# THE MECHANICAL ENGINEER'S POCKET-BOOK OF TABLES, FORMULAE, ...

Daniel Kinnear Clark

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# THE MECHANICAL ENGINEER POCKET-BOOK

OF

## Tables, Formulæ, Rules, and Data

*A HANDY BOOK OF REFERENCE FOR DAILY USE IN ENGINEERING PRACTICE*

BY


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"RAILWAY MACHINERY;" "TRAMWAYS;" "THE STEAM ENGINE;"
"A MANUAL OF RULES, TABLES, AND DATA," ETC.


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# PREFACE.

MANY works of the POCKET-BOOK class have already been published for the use of professional men; but not one of those with which I am acquainted has been compiled expressly with a view to the requirements of the Mechanical Engineer.

This POCKET-BOOK has accordingly been prepared for the purpose of shortening the calculations and other intricate mental operations which are amongst the daily recurring needs of mechanical men. To meet such needs, there will be found in the following pages about 350 Tables of results of calculations, relating to the principal branches of mechanical practice, which have either been compiled anew, or drawn from various sources. There are, in addition, about 500 Formulæ and Rules, with Data of general utility, classified for ready reference. By their aid, many a weary search in larger and more ambitious books may be dispensed with, and the labour of calculation greatly abridged, or even entirely avoided.

I do not lay especial claim in these pages to origi-

nality, for much of the matter of the book is necessarily common property. I have, nevertheless, contributed many original tables, formulæ, and data, herein published for the first time. And with regard to all matter in the work, I have spared no pains, on the one hand, to select such questions as the mechanical engineer would probably most desire to find elucidated; and on the other, to draw my material from the best and most trustworthy sources.

Besides the usual indispensable mathematical tables, and rules for measurement of surfaces and solids, full tables of English weights and measures, with French metric equivalents, are given; tables of French metric weights and measures, with equivalent English values, are also given.

Many useful tables are given of the weights and strength of bars, sheets, beams, joists, girders, tubes, pipes, bolts and nuts, cylinders, nails, chains, and other manufactured pieces. For the strength of materials, a variety of experimental evidence is given, with many new formulæ and tables. Heat and its applications have been fully considered in various aspects. The best proportions of steam engines, simple and compound, are discussed; together with pumping engines, water power, and compressed-air power.

I am indebted to Mr. H. R. Kempe, A.M.I.C.E., for his assistance in the preparation of the section on Electrical Engineering; and in various sections acknowledgment will be found duly made of my indebtedness to other authorities.

I am in hopes that the variety of matter here pre-

sented will meet all reasonable requirements of practical men in such a work, and enable them to dispense very largely with exterior aid.

At the same time, I shall be glad to avail myself of the hints or suggestions of mechanical men using the book, with a view to improve and to perfect its contents; and I shall receive with pleasure communications which may be made to me from any quarter with that object.

D. K. CLARK.

LONDON, *November*, 1891.

## NOTE TO SECOND EDITION.

IN preparing the second edition of this POCKET-BOOK for the press, I have taken advantage of the opportunity to import various new matters into the text, and, at the same time, to revise or alter the text where it has been found necessary.

I may again remind my readers that I am open to hints or suggestions with a view to improve or perfect the contents of this book; and that I shall receive them with pleasure.

D. K. CLARK.

LONDON, *January*, 1893.

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## Weights and Measures.



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# MECHANICAL ENGINEER'S POCKET-BOOK.

## MATHEMATICAL TABLES.

### Introduction to the Tables.

TABLE 1.—*Circumferences and Areas of Circles, Squares, Cubes, Square Roots, and Cube Roots of Numbers, from* 1 *to* 1000.

THE powers and roots of numbers may be calculated by means of logarithms; but this table will considerably economise calculation.

The columns of squares and cubes may be utilised inversely, for finding in the first column the roots of numbers contained in those columns.

The columns of square roots and cube roots, also, may be utilised for finding, in the first column, the squares and cubes of numbers containing decimals in those columns.

Further, the squares in the fourth column are the fourth powers of the square roots in the sixth column.

Again, any number in the first column may be conceived to consist of an integer and decimals, when the corresponding square or cube, with a decimal point suitably placed, will be the square or the cube of the assumed number. For example, suppose that the number 186 represents 18·6, or 1·86, or ·186, the square will contain two, or four, or six places of decimals respectively; and the cube will contain three, or six, or nine places of decimals respectively. Thus,—

| Number. | Square. | Cube. |
|---|---|---|
| 186 | 34,596 | 6,434,856 |
| 18·6 | 345·96 | 6,434·856 |
| 1·86 | 3·4596 | 6·434856 |
| ·186 | ·034596 | ·006434856 |

The number of places of decimals is fixed in each instance according to the common rule of twice the number of decimal places in the original number for a square, and three times the number in the original for a cube.

TABLE 2.—*Diameter, Circumference, and Area of Circles, advancing by Vulgar Fractions, from* $\frac{1}{64}$ *to* 120.

The diameters specifically represent lengths in inches and parts of inches. But they may represent values in any other units, as feet or yards.

TABLE 3.—*Reciprocals of Numbers, from* 1 *to* 1000.

The reciprocal of a number is the quotient obtained by dividing 1 by the given number.

The product of any number with its reciprocal is equal to 1. Hence a ready means of checking the accuracy of any reciprocal, which when multiplied by its number should give a quotient of 1.

The reciprocal of a vulgar fraction is equal to the quotient of the denominator by the enumerator. Thus the reciprocal of $\frac{1}{2}$ is equal to $\left(\frac{2}{1} =\right)$ 2. Or, the vulgar fraction may be reduced to a decimal form, and the decimal value divided into 1. Thus $\frac{1}{2} = \cdot 5$, and $1 \div \cdot 5 = 2$.

TABLE 4.—*Logarithms of Numbers, from* 1 *to* 10,000.

Logarithms are designed to abbreviate calculations involving multiplication and division of numbers, by the substitution of calculations by addition and subtraction respectively. Logarithms consist of integers and decimals, and they are given in Table 4 for numbers ranging from 1 to 10,000. The integers or indices, as they are called, are, except in the small preliminary tablet, omitted in the table, for the sake of brevity, but chiefly for the sake of clearness and simplicity. The decimal values of the logarithms are given to six places. The integer or index of each logarithm is less by 1 than the number of places in the integer of the number; and if the number contain only decimals, the index is equal to the number of cyphers next the decimal point, plus 1. The index in this case is negative, and is so distinguished by the sign minus, $-$, written over it. The adjustment of the integer of a logarithm to the composition of the given number is exemplified in the following series, in which the same number is repeated several

times, having the decimal point shifted regularly by one digit towards the left :—

| | |
|---|---|
| 5314 | 3·725422 |
| 531·4 | 2·725422 |
| 53·14 | 1·725422 |
| 5·314 | 0·725422 |
| ·5314 | $\bar{1}$·725422 |
| ·05314 | $\bar{2}$·725422 |
| ·005314 | $\bar{3}$·725422 |

*To find the logarithm of a number.* If the number contain only one or two digits, look for it in the columns marked N in the preliminary tablet, and find the logarithm next to it, or, look for the number in the body of the table, with one, or two, cyphers following it ; and the decimal part of the logarithm stands next to the number, in the column headed 0. For example, the decimal part of the logarithm of 5, ·698970, is in the column next to 500, in page 63 of the table ; corresponding to the single digit in the integer, the integral figure of the logarithm is 0, and the complete logarithm is 0·698970. For 50, the logarithm is 1·698970 ; and for 500, the logarithm is 2·698970 ; but for ·5, the logarithm is $\bar{1}$·698970.

In short, if the given number consist of one. two, or three digits, the decimal part of its logarithm is found in the column headed 0. If the number consist of four digits, look for the first, second, and third in the column N, and the fourth in the row of headings or footings at the top or the bottom of the table ; and the logarithmic decimal is found opposite the number in the marginal column, and below or above the fourth. If the number consist of five or more digits, the logarithm for the first to the fourth digits being found as above, multiply the corresponding difference in the last column, D, by the remaining digits, and divide by 10 if there be only one digit more. by 100 if there be ten more, and so on. Add the quotient to the logarithm already obtained. to give the logarithm required. For example. to find the logarithm of 62·355. The decimal part of the logarithm of 6235 is ·794836, and the corresponding difference ($70 \times 5 \div 10 =$) 35, is to be added, thus—

0·794836
35

0·794871 the completed logarithm.

Conversely, the number for a given logarithm is found by searching for the decimal part of the logarithm. If it be found exactly or within a few units of the right-hand digit,

note the first, second, and third digits of the required number in the column N, and the fourth digit at the top or the bottom, above or below the decimal; and place the decimal point. If the logarithm differ materially from the nearest in the table, find the number for the next less logarithm in the table, to give the first, second, third, and fourth digits. To find the fifth and, if necessary, the sixth digit, subtract the tabulated logarithm from the given logarithm, add two cyphers, and divide by the difference found in column D in a line with the logarithm. Annex the quotient to the four digits already found, and place the decimal point. For example, to find the number represented by the logarithm 0·497151. The nearest less logarithm in the table is 0·497068, for the number 3141. Subtracting this logarithm from that, thus—

$$\begin{array}{r} 0{\cdot}497151 \\ 0{\cdot}497068 \\ \hline 83 \end{array}$$

add two cyphers to the difference, making 8300, and divide by 138, the difference in column D. Then $8300 \div 138 = 60$, and annexing 60 to 3141, the number is 314160. Placing the decimal point, the completed number is 3·14160, or 3·1416.

*To multiply two or more numbers together*, add together their logarithms. The sum is the logarithm of the product. To divide one number by another, subtract the logarithm of this from the logarithm of that; the number corresponding to the difference is the quotient.

*To find any power of a given number*, multiply the logarithm of the number by the exponent of the power. The product is the logarithm of the power.

*To find any root of a given number*, divide the logarithm of the number by the index of the root.

*To find the reciprocal of a given number*, subtract the decimal part of the logarithm of the number from 0·000000: add 1 to the index of the logarithm and change the sign of the index. For example, to find the reciprocal of 350:—

$$\begin{array}{lr} & 0{\cdot}000000 \\ \text{log. } 350 \quad . \quad . & 2{\cdot}544068 \\ \hline & \bar{3}{\cdot}455932 = \text{log. } {\cdot}002857. \end{array}$$

Conversely, to find the reciprocal of the decimal ·002857:—

$$\begin{array}{lr} & 0{\cdot}000000 \\ \text{log. } {\cdot}002857 \quad . & \bar{3}{\cdot}455932 \\ \hline & 2{\cdot}544068 = \text{log. } 350. \end{array}$$

These two calculations afford examples of negative indices. In the first, the logarithm of 350 has the index 2, or + 2, the sign of which is changed for subtraction, making − 2. In deducting the digit 5, the first decimal, from 0, 1 is carried to it from the previous subtraction, making 6, which deducted from 10 leaves 4. Carrying 1, − 2 and − 1 make − 3, which is the index of the remainder, $\bar{3}$·455932, the logarithm of ·002857.

In the second calculation above, in deducting the first decimal, 4 augmented by 1 carried, or 5, from 10, there remains 5, the first decimal in the remainder; and 1 is carried to the index place. But, first, the sign of the index is changed, and the index becomes + 3; and from this the carried 1 is deducted, leaving + 2 the index of the remaining logarithm of 350.

*To add together two negative indices*, they are simply added and the negative sign placed over the sum, thus $\bar{3} + \bar{2} = \bar{5}$. In the addition together of a positive index and a negative index, their difference is the sum, bearing the sign of the greater additive; thus $3 + \bar{2} = 1$; or $2 + \bar{3} = \bar{1}$. For example:—

$$\begin{aligned} \text{log. } 3442 &= 3·536811 \\ \text{log. } ·02801 &= \bar{2}·447313 \\ \hline \text{log. } 96·41 &= 1·984124 \end{aligned}$$

*To subtract a negative index*, change the sine and add. Thus, to subtract $\bar{2}$ from $\bar{3}$, there is $\bar{3} + 2 = \bar{1}$; but this may be done simply thus $\bar{3} - \bar{2} = \bar{1}$. Again, $\bar{3}$ from $2 = 3 + 2 = 5$. To subtract a positive index from a negative index, change the positive sign to negative and add; thus, 3 from $\bar{5} = \bar{3} + \bar{5} = \bar{8}$.

*To find a root of a given number.* Divide the logarithm of the number by the exponent of the root: the quotient is the logarithm of the root. If the index be negative, and is divisible without a remainder, the quotient of the index is negative. If it be not so divisible, add to it so much in the negative as will make it divisible, and divide it, to give the index, which is negative; prefix an equal quantity to the decimal part of the logarithm, and divide separately. The two quotients together make the logarithm of the root. For example, to find the square root of 1849:—

$$\begin{aligned} \text{log. } 1849 &= 3·266937 \\ \text{divided by } 2 &= 1·633469 = \text{log. } 43. \end{aligned}$$

To find the fourth root of ·00578 :—

$$\log. \cdot 00578 = \bar{3}\cdot 761928$$
$$\text{divide by 4, say } \bar{4} + 1\cdot 761928$$
$$\text{giving } \bar{1}\cdot 440482 = \log. \cdot 2757.$$

It is, in ordinary practice, for the most part, unnecessary to note the indices of logarithms, as the numbers are mostly sufficiently indicated without the indices. Besides, in many cases, rough approximations suffice, particularly where numbers are expressed wholly or partly in decimals.

TABLE 5.—*Hyperbolic Logarithms of Numbers from* 1·01 *to* 20.

The table of hyperbolic logarithms is useful chiefly in calculations of the work of steam by expansion. The numbers range from 1·01 to 20. Hyperbolic, or Neperian, logarithms, are calculated by multiplying the common logarithms of numbers, as given in Table 4, by the constant multiplier 2·302585.

TABLE 6.—*Sines and Cosines of Angles from* 0° to 90°.

The tabulated values are the proportional values when the length of the radius of the circle is taken as 1. When the actual length of the radius is given, the actual length of any sine or cosine is found by multiplying the tabular value by the length of the radius.

The table is arranged so that each value signifies the sine of an angle and the cosine of its complement for 90 degrees. The values are given for angles advancing by half a degree. The values for intermediate angles, sufficiently near exactness for most purposes, can be found by interpolation in simple proportion. By an inverse operation, the angle may be found for any given sine or cosine not given in the table.

TABLE 7.—*Tangents and Cotangents of Angles from* 0° *to* 90°.

The values are, like those of the sines and cosines, proportional values, the radius being taken as 1. The actual values of the tangents and cotangents are calculated by multiplying the actual length of the radius by the corresponding tabular value of the tangent or the cotangent.

Each tabular value is that of the tangent of an angle, and also that of the cotangent of the complementary angle. The values are given for angles advancing by half a degree; and values for intermediate angles may be found by interpolation. Inversely, the angle may be found for any given tangent or cotangent not found in the table.

TABLE 8.—*Lengths of Circular Arcs, from* 1° *to* 180°.

The lengths of circular arcs of which the magnitudes in degrees are given, are stated in proportion to the length of the radius, taken as 1. The actual length of the arc is found by multiplying the actual length of the radius by the tabular length corresponding to the number of degrees in the arc.

TABLE 9.—*Lengths of Circular Arcs, up to a Semicircle, when the Chord is given.*

In this table, the length of the arc is given proportionally to the length of the chord, which is taken as 1. The heights of the arcs in the table are the quotients arising by dividing the actual heights by the actual lengths of the chords, and are the ratios of the heights to the chords.

To use the table, therefore, divide the height of the arc by the length of the chord; find the quotient in the columns of heights in the table, and multiply the corresponding tabular length of the arc by the actual length of the chord. The product is the length of the arc.

TABLE 10.—*Areas of Circular Segments.*

The tabular areas of circular segments are in proportional superficial measure, corresponding to the length of the diameter, which is taken as 1. The tabular heights of the segments are the quotients of the heights divided by the diameters; the relative areas are given in the columns of areas.

To use the table, divide the actual height by the actual diameter, find the quotient in the columns of heights; and multiply the corresponding tabular area by the square of the actual length of the diameter. The product is the actual area.

TABLE 11.—*Lengths of Semi-Elliptic Arcs up to a Semi-Circle.*

This table has been calculated by means of Mr. Trautwine's formula. In the columns of heights are the ratios of the rise to the span or chord of an elliptic arc. To use the table, divide the given rise by the chord, and find the quotient in the columns of heights. Next to this quotient, in the adjoining column, is a multiplier, which when multiplied by the actual length of the span, gives the length of the arc.

### TABLE 1.—NUMBERS (FROM 1 TO 1,000), OR DIAMETERS OF CIRCLES, CIRCUMFERENCES, AREAS, SQUARES, CUBES, SQUARE ROOTS, AND CUBE ROOTS.*

| No. or Diam. | Circumference. | Circular Area. | Square. | Cube. | Square Root. | Cube Root. |
|---|---|---|---|---|---|---|
| 1 | 3·1416 | 0·7854 | 1 | 1 | 1·000 | 1·000 |
| 2 | 6·2832 | 3·1416 | 4 | 8 | 1·414 | 1·259 |
| 3 | 9·4248 | 7·0686 | 9 | 27 | 1·732 | 1·442 |
| 4 | 12·57 | 12·57 | 16 | 64 | 2·000 | 1·587 |
| 5 | 15·71 | 19·63 | 25 | 125 | 2·236 | 1·709 |
| 6 | 18·85 | 28·27 | 36 | 216 | 2·449 | 1·817 |
| 7 | 21·99 | 38·48 | 49 | 343 | 2·645 | 1·912 |
| 8 | 25·13 | 50·27 | 64 | 512 | 2·828 | 2·000 |
| 9 | 28·27 | 63·62 | 81 | 729 | 3·000 | 2·080 |
| 10 | 31·42 | 78·54 | 100 | 1,000 | 3·162 | 2·154 |
| 11 | 34·56 | 95·03 | 121 | 1,331 | 3·316 | 2·223 |
| 12 | 37·70 | 113·10 | 144 | 1,728 | 3·464 | 2·289 |
| 13 | 40·84 | 132·73 | 169 | 2,197 | 3·605 | 2·351 |
| 14 | 43·98 | 153·94 | 196 | 2,744 | 3·741 | 2·410 |
| 15 | 47·12 | 176·71 | 225 | 3,375 | 3·872 | 2·466 |
| 16 | 50·26 | 201·06 | 256 | 4,096 | 4·000 | 2·519 |
| 17 | 53·41 | 226·98 | 289 | 4,913 | 4·123 | 2·571 |
| 18 | 56·55 | 254·47 | 324 | 5,832 | 4·242 | 2·620 |
| 19 | 59·69 | 283·53 | 361 | 6,859 | 4·358 | 2·668 |
| 20 | 62·83 | 314·16 | 400 | 8,000 | 4·472 | 2·714 |
| 21 | 65·97 | 346·36 | 441 | 9,261 | 4·582 | 2·758 |
| 22 | 69·11 | 380·13 | 484 | 10,648 | 4·690 | 2·802 |
| 23 | 72·26 | 415·48 | 529 | 12,167 | 4·795 | 2·843 |
| 24 | 75·40 | 452·39 | 576 | 13,824 | 4·898 | 2·884 |
| 25 | 78·54 | 490·87 | 625 | 15,625 | 5·000 | 2·924 |
| 26 | 81·68 | 530·93 | 676 | 17,576 | 5·099 | 2·962 |
| 27 | 84·82 | 572·56 | 729 | 19,683 | 5·196 | 3·000 |
| 28 | 87·96 | 615·75 | 784 | 21,952 | 5·291 | 3·036 |
| 29 | 91·11 | 660·52 | 841 | 24,389 | 5·385 | 3·072 |
| 30 | 94·25 | 706·86 | 900 | 27,000 | 5·477 | 3·107 |
| 31 | 97·39 | 754·77 | 961 | 29,791 | 5·567 | 3·141 |
| 32 | 100·53 | 804·25 | 1,024 | 32,768 | 5·656 | 3·174 |
| 33 | 103·67 | 855·30 | 1,089 | 35,937 | 5·744 | 3·207 |
| 34 | 106·81 | 907·92 | 1,156 | 39,304 | 5·830 | 3·239 |
| 35 | 109·96 | 962·11 | 1,225 | 42,875 | 5·916 | 3·271 |
| 36 | 113·10 | 1017·88 | 1,296 | 46,656 | 6·000 | 3·301 |
| 37 | 116·24 | 1075·21 | 1,369 | 50,653 | 6·082 | 3·332 |
| 38 | 119·38 | 1131·11 | 1,444 | 54,872 | 6·164 | 3·361 |
| 39 | 122·52 | 1194·59 | 1,521 | 59,319 | 6·244 | 3·391 |

* See Introduction, *ante*, p. 1.

| No. or Diam. | Circumference. | Circular Area. | Square. | Cube. | Square Root. | Cube Root. |
|---|---|---|---|---|---|---|
| **40** | 125·66 | 1256·64 | 1,600 | 64,000 | 6·326 | 3·419 |
| **41** | 128·80 | 1320·25 | 1,681 | 68,921 | 6·403 | 3·448 |
| **42** | 131·95 | 1385·44 | 1,764 | 74,088 | 6·480 | 3·476 |
| **43** | 135·09 | 1452·20 | 1,849 | 79,507 | 6·557 | 3·503 |
| **44** | 138·23 | 1520·53 | 1,936 | 85,184 | 6·633 | 3·530 |
| **45** | 141·37 | 1590·43 | 2,025 | 91,125 | 6·708 | 3·556 |
| **46** | 144·51 | 1661·90 | 2,116 | 97,336 | 6·782 | 3·583 |
| **47** | 147·65 | 1734·94 | 2,209 | 103,823 | 6·855 | 3·608 |
| **48** | 150·80 | 1809·56 | 2,304 | 110,592 | 6·928 | 3·634 |
| **49** | 153·94 | 1885·74 | 2,401 | 117,649 | 7·000 | 3·659 |
| **50** | 157·08 | 1963·50 | 2,500 | 125,000 | 7·071 | 3·684 |
| **51** | 160·22 | 2042·82 | 2,601 | 132,651 | 7·141 | 3·708 |
| **52** | 163·36 | 2123·72 | 2,704 | 140,608 | 7·211 | 3·732 |
| **53** | 166·50 | 2205·18 | 2,809 | 148,877 | 7·280 | 3·756 |
| **54** | 169·65 | 2290·22 | 2,916 | 157,464 | 7·348 | 3·779 |
| **55** | 172·79 | 2375·83 | 3,025 | 166,375 | 7·416 | 3·802 |
| **56** | 175·93 | 2463·01 | 3,136 | 175,616 | 7·483 | 3·825 |
| **57** | 179·07 | 2551·76 | 3,249 | 185,193 | 7·549 | 3·848 |
| **58** | 182·21 | 2642·08 | 3,364 | 195,112 | 7·615 | 3·870 |
| **59** | 185·35 | 2733·97 | 3,481 | 205,379 | 7·681 | 3·892 |
| **60** | 188·50 | 2827·43 | 3,600 | 216,000 | 7·745 | 3·914 |
| **61** | 191·64 | 2922·47 | 3,721 | 226,981 | 7·810 | 3·936 |
| **62** | 194·78 | 3019·07 | 3,844 | 238,328 | 7·874 | 3·957 |
| **63** | 197·92 | 3117·25 | 3,969 | 250,047 | 7·937 | 3·979 |
| **64** | 201·06 | 3216·99 | 4,096 | 262,144 | 8·000 | 4·000 |
| **65** | 204·20 | 3318·31 | 4,225 | 274,625 | 8·062 | 4·020 |
| **66** | 207·34 | 3421·19 | 4,356 | 287,496 | 8·124 | 4·041 |
| **67** | 210·49 | 3525·65 | 4,489 | 300,763 | 8·185 | 4·061 |
| **68** | 213·63 | 3631·68 | 4,624 | 314,432 | 8·246 | 4·081 |
| **69** | 216·77 | 3739·28 | 4,761 | 328,509 | 8·306 | 4·101 |
| **70** | 219·91 | 3848·45 | 4,900 | 343,000 | 8·366 | 4·121 |
| **71** | 223·05 | 3959·19 | 5,041 | 357,911 | 8·426 | 4·140 |
| **72** | 226·19 | 4071·50 | 5,184 | 373,248 | 8·485 | 4·160 |
| **73** | 229·34 | 4185·39 | 5,329 | 389,017 | 8·544 | 4·179 |
| **74** | 232·48 | 4300·84 | 5,476 | 405,224 | 8·602 | 4·198 |
| **75** | 235·62 | 4417·86 | 5,625 | 421,875 | 8·660 | 4·217 |
| **76** | 238·76 | 4536·46 | 5,776 | 438,976 | 8·717 | 4·235 |
| **77** | 241·90 | 4656·63 | 5,929 | 456,533 | 8·744 | 4·254 |
| **78** | 245·04 | 4778·36 | 6,084 | 474,552 | 8·831 | 4·272 |
| **79** | 248·19 | 4901·67 | 6,241 | 493,039 | 8·888 | 4·290 |
| **80** | 251·33 | 5026·55 | 6,400 | 512,000 | 8·944 | 4·308 |
| **81** | 254·47 | 5153·00 | 6,561 | 531,441 | 9·000 | 4·326 |

| No. or Diam. | Circumference. | Circular Area. | Square. | Cube. | Square Root. | Cube Root. |
|---|---|---|---|---|---|---|
| 82 | 257·61 | 5281·02 | 6,724 | 551,368 | 9·055 | 4·344 |
| 83 | 260·75 | 5410·61 | 6,889 | 571,787 | 9·110 | 4·362 |
| 84 | 263·89 | 5541·77 | 7,056 | 592,704 | 9·165 | 4·379 |
| 85 | 267·03 | 5674·50 | 7,225 | 614,125 | 9·219 | 4·396 |
| 86 | 270·18 | 5808·80 | 7,396 | 636,056 | 9·273 | 4·414 |
| 87 | 273·32 | 5944·68 | 7,569 | 658,503 | 9·327 | 4·431 |
| 88 | 276·46 | 6082·12 | 7,744 | 681,472 | 9·380 | 4·447 |
| 89 | 279·60 | 6221·14 | 7,921 | 704,969 | 9·433 | 4·461 |
| 90 | 282·74 | 6361·73 | 8,100 | 729,000 | 9·486 | 4·481 |
| 91 | 285·88 | 6503·88 | 8,281 | 753,571 | 9·539 | 4·497 |
| 92 | 289·03 | 6647·61 | 8,464 | 778,688 | 9·591 | 4·514 |
| 93 | 292·17 | 6792·91 | 8,649 | 804,357 | 9·643 | 4·530 |
| 94 | 295·31 | 6939·78 | 8,836 | 830,584 | 9·695 | 4·546 |
| 95 | 298·45 | 7088·22 | 9,025 | 857,375 | 9·746 | 4·562 |
| 96 | 301·59 | 7238·23 | 9,216 | 884,736 | 9·797 | 4·578 |
| 97 | 304·73 | 7389·81 | 9,409 | 912,673 | 9·848 | 4·594 |
| 98 | 307·88 | 7542·96 | 9,604 | 941,192 | 9·899 | 4·610 |
| 99 | 311·02 | 7697·69 | 9,801 | 970,299 | 9·949 | 4·626 |
| 100 | 314·16 | 7853·98 | 10,000 | 1,000,000 | 10·000 | 4·641 |
| 101 | 317·30 | 8011·85 | 10,201 | 1,030,301 | 10·049 | 4·657 |
| 102 | 320·44 | 8171·28 | 10,404 | 1,061,208 | 10·099 | 4·672 |
| 103 | 323·58 | 8332·29 | 10,609 | 1,092,727 | 10·148 | 4·687 |
| 104 | 326·73 | 8494·87 | 10,816 | 1,124,864 | 10·198 | 4·702 |
| 105 | 329·87 | 8659·01 | 11,025 | 1,157,625 | 10·246 | 4·717 |
| 106 | 333·01 | 8824·73 | 11,236 | 1,191,016 | 10·295 | 4·732 |
| 107 | 336·15 | 8992·02 | 11,449 | 1,225,043 | 10·344 | 4·747 |
| 108 | 339·29 | 9160·88 | 11,664 | 1,259,712 | 10·392 | 4·762 |
| 109 | 342·43 | 9331·32 | 11,881 | 1,295,029 | 10·440 | 4·776 |
| 110 | 345·57 | 9503·32 | 12,100 | 1,331,000 | 10·488 | 4·791 |
| 111 | 348·72 | 9676·89 | 12,321 | 1,367,631 | 10·535 | 4·805 |
| 112 | 351·86 | 9852·03 | 12,544 | 1,404,928 | 10·583 | 4·820 |
| 113 | 355·00 | 10028·75 | 12,769 | 1,442,897 | 10·630 | 4·834 |
| 114 | 358·14 | 10207·03 | 12,996 | 1,481,544 | 10·677 | 4·848 |
| 115 | 361·28 | 10386·89 | 13,225 | 1,520,875 | 10·723 | 4·862 |
| 116 | 364·42 | 10568·32 | 13,456 | 1,560,896 | 10·770 | 4·876 |
| 117 | 367·57 | 10751·32 | 13,689 | 1,601,613 | 10·816 | 4·890 |
| 118 | 370·71 | 10935·88 | 13,924 | 1,643,032 | 10·862 | 4·904 |
| 119 | 373·85 | 11122·02 | 14,161 | 1,685,159 | 10·908 | 4·918 |
| 120 | 376·99 | 11309·73 | 14,400 | 1,728,000 | 10·954 | 4·932 |
| 121 | 380·13 | 11499·01 | 14,641 | 1,771,561 | 11·000 | 4·946 |
| 122 | 383·27 | 11689·87 | 14,884 | 1,815,848 | 11·045 | 4·959 |
| 123 | 386·42 | 11882·29 | 15,129 | 1,860,867 | 11·090 | 4·973 |

| No. or Diam. | Circumference. | Circular Area. | Square. | Cube. | Square Root. | Cube Root. |
|---|---|---|---|---|---|---|
| **124** | 389·56 | 12076·28 | 15,376 | 1,906,624 | 11·135 | 4·986 |
| **125** | 392·70 | 12271·85 | 15,625 | 1,953,125 | 11·180 | 5·000 |
| **126** | 395·84 | 12468·98 | 15,876 | 2,000,376 | 11·224 | 5·013 |
| **127** | 398·98 | 12667·69 | 16,129 | 2,048,383 | 11·269 | 5·026 |
| **128** | 402·12 | 12867·96 | 16,384 | 2,097,152 | 11·313 | 5·039 |
| **129** | 405·26 | 13069·81 | 16,641 | 2,146,689 | 11·357 | 5·052 |
| **130** | 408·41 | 13273·23 | 16,900 | 2,197,000 | 11·401 | 5·065 |
| **131** | 411·55 | 13478·22 | 17,161 | 2,248,091 | 11·445 | 5·078 |
| **132** | 414·69 | 13684·78 | 17,424 | 2,299,968 | 11·489 | 5·091 |
| **133** | 417·83 | 13892·91 | 17,689 | 2,352,637 | 11·532 | 5·104 |
| **134** | 420·97 | 14102·61 | 17,956 | 2,406,104 | 11·575 | 5·117 |
| **135** | 424·11 | 14313·88 | 18,225 | 2,460,375 | 11·618 | 5·129 |
| **136** | 427·26 | 14526·72 | 18,496 | 2,515,456 | 11·661 | 5·142 |
| **137** | 430·40 | 14741·14 | 18,769 | 2,571,353 | 11·704 | 5·155 |
| **138** | 433·54 | 14957·12 | 19,044 | 2,620,872 | 11·747 | 5·167 |
| **139** | 436·68 | 15174·68 | 19,321 | 2,685,619 | 11·789 | 5·180 |
| **140** | 439·82 | 15393·80 | 19,600 | 2,744,000 | 11·832 | 5·192 |
| **141** | 442·96 | 15614·50 | 19,881 | 2,803,221 | 11·874 | 5·204 |
| **142** | 446·11 | 15836·77 | 20,164 | 2,863,288 | 11·916 | 5·217 |
| **143** | 449·25 | 16060·61 | 20,449 | 2,924,207 | 11·958 | 5·229 |
| **144** | 452·39 | 16286·02 | 20,736 | 2,985,984 | 12·000 | 5·241 |
| **145** | 455·53 | 16513·00 | 21,025 | 3,048,625 | 12·041 | 5·253 |
| **146** | 458·67 | 16741·55 | 21,316 | 3,112,136 | 12·083 | 5·265 |
| **147** | 461·81 | 16971·67 | 21,609 | 3,176,523 | 12·124 | 5·277 |
| **148** | 464·96 | 17203·36 | 21,904 | 3,241,792 | 12·165 | 5·289 |
| **149** | 468·10 | 17436·62 | 22,201 | 3,307,949 | 12·206 | 5·301 |
| **150** | 471·24 | 17671·46 | 22,500 | 3,375,000 | 12·247 | 5·313 |
| **151** | 474·38 | 17907·86 | 22,801 | 3,442,951 | 12·288 | 5·325 |
| **152** | 477·52 | 18145·84 | 23,104 | 3,511,808 | 12·328 | 5·336 |
| **153** | 480·66 | 18385·39 | 23,409 | 3,581,577 | 12·369 | 5·348 |
| **154** | 483·80 | 18626·50 | 23,716 | 3,652,264 | 12·409 | 5·360 |
| **155** | 486·95 | 18869·19 | 24,025 | 3,723,875 | 12·449 | 5·371 |
| **156** | 490·09 | 19113·45 | 24,336 | 3,796,416 | 12·489 | 5·383 |
| **157** | 493·23 | 19359·28 | 24,649 | 3,869,893 | 12·529 | 5·394 |
| **158** | 496·37 | 19606·68 | 24,964 | 3,944,312 | 12·569 | 5·406 |
| **159** | 499·51 | 19855·65 | 25,281 | 4,019,679 | 12·609 | 5·417 |
| **160** | 502·65 | 20106·19 | 25,600 | 4,096,000 | 12·649 | 5·428 |
| **161** | 505·80 | 20358·34 | 25,921 | 4,173,281 | 12·688 | 5·440 |
| **162** | 508·94 | 20611·99 | 26,244 | 4,251,528 | 12·727 | 5·451 |
| **163** | 512·08 | 20867·24 | 26,569 | 4,330,747 | 12·767 | 5·462 |
| **164** | 515·22 | 21124·07 | 26,896 | 4,410,944 | 12·806 | 5·473 |
| **165** | 518·36 | 21382·46 | 27,225 | 4,492,125 | 12·845 | 5·484 |

| No. or Diam. | Circumference. | Circular Area. | Square. | Cube. | Square Root. | Cube Root. |
|---|---|---|---|---|---|---|
| 166 | 521·50 | 21642·43 | 27,556 | 4,574,296 | 12·844 | 5·495 |
| 167 | 524·65 | 21903·97 | 27,889 | 4,657,463 | 12·922 | 5·506 |
| 168 | 527·79 | 22167·08 | 28,224 | 4,741,632 | 12·961 | 5·517 |
| 169 | 530·93 | 22431·76 | 28,561 | 4,826,809 | 13·000 | 5·528 |
| 170 | 534·07 | 22698·01 | 28,900 | 4,913,000 | 13·038 | 5·539 |
| 171 | 537·21 | 22965·83 | 29,241 | 5,000,211 | 13·076 | 5·550 |
| 172 | 540·35 | 23235·22 | 29,584 | 5,088,448 | 13·114 | 5·561 |
| 173 | 543·50 | 23506·18 | 29,929 | 5,177,717 | 13·152 | 5·572 |
| 174 | 546·64 | 23778·71 | 30,276 | 5,268,024 | 13·190 | 5·582 |
| 175 | 549·78 | 24052·82 | 30,625 | 5,359,375 | 13·228 | 5·593 |
| 176 | 552·92 | 24328·49 | 30,976 | 5,451,776 | 13·266 | 5·604 |
| 177 | 556·06 | 24605·79 | 31,329 | 5,545,233 | 13·304 | 5·614 |
| 178 | 559·20 | 24884·56 | 31,684 | 5,639,752 | 13·341 | 5·625 |
| 179 | 562·34 | 25164·94 | 32,041 | 5,735,339 | 13·379 | 5·635 |
| 180 | 565·49 | 25446·90 | 32,400 | 5,832,000 | 13·416 | 5·646 |
| 181 | 568·63 | 25730·43 | 32,761 | 5,929,741 | 13·453 | 5·656 |
| 182 | 571·77 | 26015·53 | 33,124 | 6,028,568 | 13·490 | 5·667 |
| 183 | 574·91 | 26302·20 | 33,489 | 6,128,487 | 13·527 | 5·677 |
| 184 | 578·05 | 26590·44 | 33,856 | 6,229,504 | 13·564 | 5·687 |
| 185 | 581·19 | 26880·25 | 34,225 | 6,331,625 | 13·601 | 5·698 |
| 186 | 584·34 | 27171·63 | 34,596 | 6,434,856 | 13·638 | 5·708 |
| 187 | 587·48 | 27464·59 | 34,969 | 6,539,203 | 13·674 | 5·718 |
| 188 | 590·62 | 27759·11 | 35,344 | 6,644,672 | 13·711 | 5·728 |
| 189 | 593·76 | 28055·21 | 35,721 | 6,751,269 | 13·747 | 5·738 |
| 190 | 596·90 | 28352·87 | 36,100 | 6,859,000 | 13·784 | 5·748 |
| 191 | 600·04 | 28652·11 | 36,481 | 6,967,871 | 13·820 | 5·758 |
| 192 | 603·19 | 28952·92 | 36,864 | 7,077,888 | 13·856 | 5·768 |
| 193 | 606·33 | 29255·30 | 37,249 | 7,189,057 | 13·892 | 5·778 |
| 194 | 609·47 | 29559·26 | 37,636 | 7,301,384 | 13·928 | 5·788 |
| 195 | 612·61 | 29864·77 | 38,025 | 7,414,875 | 13·964 | 5·798 |
| 196 | 615·75 | 30171·86 | 38,416 | 7,529,536 | 14·000 | 5·808 |
| 197 | 618·89 | 30480·52 | 38,809 | 7,645,373 | 14·035 | 5·818 |
| 198 | 622·03 | 30790·75 | 39,204 | 7,762,392 | 14·071 | 5·828 |
| 199 | 625·18 | 31102·55 | 39,601 | 7,880,599 | 14·106 | 5·838 |
| 200 | 628·32 | 31415·93 | 40,000 | 8,000,000 | 14·142 | 5·848 |
| 201 | 631·46 | 31730·87 | 40,401 | 8,120,601 | 14·177 | 5·857 |
| 202 | 634·60 | 32047·39 | 40,804 | 8,242,408 | 14·212 | 5·867 |
| 203 | 637·74 | 32365·47 | 41,209 | 8,365,427 | 14·247 | 5·877 |
| 204 | 640·88 | 32685·13 | 41,616 | 8,489,664 | 14·282 | 5·886 |
| 205 | 644·03 | 33006·36 | 42,025 | 8,615,125 | 14·317 | 5·896 |
| 206 | 647·17 | 33329·16 | 42,436 | 8,741,816 | 14·352 | 5·905 |
| 207 | 650·31 | 33653·53 | 42,849 | 8,869,743 | 14·387 | 5·915 |

| No. or Diam. | Circumference. | Circular Area. | Square. | Cube. | Square Root. | Cube Root. |
|---|---|---|---|---|---|---|
| **208** | 653·45 | 33979·47 | 43,264 | 8,998,912 | 14·422 | 5·924 |
| **209** | 656·59 | 34306·98 | 43,681 | 9,123,329 | 14·456 | 5·934 |
| **210** | 659·73 | 34636·06 | 44,100 | 9,261,000 | 14·491 | 5·943 |
| **211** | 662·88 | 34966·71 | 44,521 | 9,393,931 | 14·525 | 5·953 |
| **212** | 666·02 | 35298·94 | 44,944 | 9,528,128 | 14·560 | 5·962 |
| **213** | 669·16 | 35632·73 | 45,369 | 9,663,597 | 14·594 | 5·972 |
| **214** | 672·30 | 35968·09 | 45,796 | 9,800,344 | 14·628 | 5·981 |
| **215** | 675·44 | 36305·03 | 46,225 | 9,938,375 | 14·662 | 5·990 |
| **216** | 678·58 | 36643·61 | 46,656 | 10,077,696 | 14·696 | 6·000 |
| **217** | 681·73 | 36983·61 | 47,089 | 10,218,313 | 14·730 | 6·009 |
| **218** | 684·87 | 37325·26 | 47,524 | 10,360,232 | 14·764 | 6·018 |
| **219** | 688·01 | 37668·48 | 47,961 | 10,503,459 | 14·798 | 6·027 |
| **220** | 691·15 | 38013·27 | 48,400 | 10,648,000 | 14·832 | 6·036 |
| **221** | 694·29 | 38359·63 | 48,841 | 10,793,861 | 14·866 | 6·045 |
| **222** | 697·43 | 38707·56 | 49,284 | 10,941,048 | 14·899 | 6·055 |
| **223** | 700·57 | 39057·07 | 49,729 | 11,089,567 | 14·933 | 6·064 |
| **224** | 703·72 | 39408·14 | 50,176 | 11,239,424 | 14·966 | 6·073 |
| **225** | 706·86 | 39760·78 | 50,625 | 11,390,625 | 15·000 | 6·082 |
| **226** | 710·00 | 40115·00 | 51,076 | 11,543,176 | 15·033 | 6·091 |
| **227** | 713·14 | 40470·78 | 51,529 | 11,697,083 | 15·066 | 6·100 |
| **228** | 716·28 | 40828·14 | 51,984 | 11,852,352 | 15·099 | 6·109 |
| **229** | 719·42 | 41187·07 | 52,441 | 12,008,989 | 15·132 | 6·118 |
| **230** | 722·57 | 41547·56 | 52,900 | 12,167,000 | 15·165 | 6·126 |
| **231** | 725·71 | 41909·63 | 53,361 | 12,326,391 | 15·198 | 6·135 |
| **232** | 728·85 | 42273·27 | 53,824 | 12,487,168 | 15·231 | 6·144 |
| **233** | 731·99 | 42638·48 | 54,289 | 12,649,337 | 15·264 | 6·153 |
| **234** | 735·13 | 43005·26 | 54,756 | 12,812,904 | 15·297 | 6·162 |
| **235** | 738·27 | 43373·61 | 55,225 | 12,977,875 | 15·329 | 6·171 |
| **236** | 741·42 | 43743·54 | 55,696 | 13,144,256 | 15·362 | 6·179 |
| **237** | 744·56 | 44115·03 | 56,169 | 13,312,053 | 15·394 | 6·188 |
| **238** | 747·70 | 44488·09 | 56,644 | 13,481,272 | 15·427 | 6·197 |
| **239** | 750·84 | 44862·73 | 57,121 | 13,651,919 | 15·459 | 6·205 |
| **240** | 753·98 | 45238·93 | 57,600 | 13,824,000 | 15·491 | 6·214 |
| **241** | 757·12 | 45616·71 | 58,081 | 13,997,521 | 15·524 | 6·223 |
| **242** | 760·26 | 45996·06 | 58,564 | 14,172,488 | 15·556 | 6·231 |
| **243** | 763·41 | 46376·98 | 59,049 | 14,348,907 | 15·588 | 6·240 |
| **244** | 766·55 | 46759·47 | 59,536 | 14,526,784 | 15·620 | 6·248 |
| **245** | 769·69 | 47143·52 | 60,025 | 14,706,125 | 15·652 | 6·257 |
| **246** | 772·83 | 47529·16 | 60,516 | 14,886,936 | 15·684 | 6·265 |
| **247** | 775·97 | 47916·36 | 61,009 | 15,069,223 | 15·716 | 6·274 |
| **248** | 779·11 | 48305·13 | 61,504 | 15,252,992 | 15·748 | 6·282 |
| **249** | 782·26 | 48695·47 | 62,001 | 15,438,249 | 15·779 | 6·291 |

| No. or Diam. | Circumference. | Circular Area. | Square. | Cube. | Square Root. | Cube Root. |
|---|---|---|---|---|---|---|
| 250 | 785·40 | 49087·39 | 62,500 | 15,625,000 | 15·811 | 6·299 |
| 251 | 788·54 | 49480·87 | 63,001 | 15,813,251 | 15·842 | 6·307 |
| 252 | 791·68 | 49875·92 | 63,504 | 16,003,008 | 15·874 | 6·316 |
| 253 | 794·82 | 50272·55 | 64,009 | 16,194,277 | 15·905 | 6·324 |
| 254 | 797·96 | 50670·75 | 64,516 | 16,387,064 | 15·937 | 6·333 |
| 255 | 801·11 | 51070·52 | 65,025 | 16,581,375 | 15·968 | 6·341 |
| 256 | 804·25 | 51471·86 | 65,536 | 16,777,216 | 16·000 | 6·349 |
| 257 | 807·39 | 51874·76 | 66,049 | 16,974,593 | 16·031 | 6·357 |
| 258 | 810·53 | 52279·24 | 66,564 | 17,173,512 | 16·062 | 6·366 |
| 259 | 813·67 | 52685·29 | 67,081 | 17,373,979 | 16·093 | 6·374 |
| 260 | 816·81 | 53092·96 | 67,600 | 17,576,000 | 16·124 | 6·382 |
| 261 | 819·96 | 53502·11 | 68,121 | 17,779,581 | 16·155 | 6·390 |
| 262 | 823·10 | 53912·87 | 68,644 | 17,984,728 | 16·186 | 6·398 |
| 263 | 826·24 | 54325·21 | 69,169 | 18,191,447 | 16·217 | 6·406 |
| 264 | 829·38 | 54739·11 | 69,696 | 18,399,744 | 16·248 | 6·415 |
| 265 | 832·52 | 55154·59 | 70,225 | 18,609,625 | 16·278 | 6·423 |
| 266 | 835·66 | 55571·63 | 70,756 | 18,821,096 | 16·309 | 6·431 |
| 267 | 838·80 | 55990·25 | 71,289 | 19,034,163 | 16·340 | 6·439 |
| 268 | 841·95 | 56410·44 | 71,824 | 19,248,832 | 16·370 | 6·447 |
| 269 | 845·09 | 56832·20 | 72,361 | 19,465,109 | 16·401 | 6·455 |
| 270 | 848·23 | 57255·53 | 72,900 | 19,683,000 | 16·431 | 6·463 |
| 271 | 851·37 | 57680·43 | 73,441 | 19,902,511 | 16·462 | 6·471 |
| 272 | 854·51 | 58106·90 | 73,984 | 20,123,648 | 16·492 | 6·479 |
| 273 | 857·65 | 58534·94 | 74,529 | 20,346,417 | 16·522 | 6·487 |
| 274 | 860·80 | 58964·55 | 75,076 | 20,570,824 | 16·552 | 6·495 |
| 275 | 863·94 | 59395·74 | 75,625 | 20,796,875 | 16·583 | 6·502 |
| 276 | 867·08 | 59828·49 | 76,176 | 21,024,576 | 16·613 | 6·510 |
| 277 | 870·22 | 60262·82 | 76,729 | 21,253,933 | 16·643 | 6·518 |
| 278 | 873·36 | 60698·72 | 77,284 | 21,484,952 | 16·673 | 6·526 |
| 279 | 876·50 | 61136·18 | 77,841 | 21,717,639 | 16·703 | 6·534 |
| 280 | 879·65 | 61575·22 | 78,400 | 21,952,000 | 16·733 | 6·542 |
| 281 | 882·79 | 62015·82 | 78,961 | 22,188,041 | 16·763 | 6·549 |
| 282 | 885·93 | 62458·00 | 79,524 | 22,425,768 | 16·792 | 6·557 |
| 283 | 889·07 | 62901·75 | 80,089 | 22,665,187 | 16·822 | 6·565 |
| 284 | 892·21 | 63347·07 | 80,656 | 22,906,304 | 16·852 | 6·573 |
| 285 | 895·35 | 63793·97 | 81,225 | 23,149,125 | 16·881 | 6·580 |
| 286 | 898·49 | 64242·43 | 81,796 | 23,393,656 | 16·911 | 6·588 |
| 287 | 901·64 | 64692·46 | 82,369 | 23,639,903 | 16·941 | 6·596 |
| 288 | 904·78 | 65144·07 | 82,944 | 23,887,872 | 16·970 | 6·603 |
| 289 | 907·92 | 65597·24 | 83,521 | 24,137,569 | 17·000 | 6·611 |
| 290 | 911·06 | 66051·99 | 84,100 | 24,389,000 | 17·029 | 6·619 |
| 291 | 914·20 | 66508·30 | 84,681 | 24,642,171 | 17·059 | 6·627 |

| No. or Diam. | Circumference. | Circular Area. | Square. | Cube. | Square Root. | Cube Root. |
|---|---|---|---|---|---|---|
| 292 | 917·34 | 66966·19 | 85,264 | 24,897,088 | 17·088 | 6·634 |
| 293 | 920·49 | 67425·65 | 85,849 | 25,153,757 | 17·117 | 6·642 |
| 294 | 923·63 | 67886·68 | 86,436 | 25,412,184 | 17·146 | 6·649 |
| 295 | 926·77 | 68349·28 | 87,025 | 25,672,375 | 17·176 | 6·657 |
| 296 | 929·91 | 68813·45 | 87,616 | 25,934,336 | 17·205 | 6·664 |
| 297 | 933·05 | 69279·19 | 88,209 | 26,198,073 | 17·234 | 6·672 |
| 298 | 936·19 | 69746·50 | 88,804 | 26,463,592 | 17·263 | 6·679 |
| 299 | 939·34 | 70215.38 | 89,401 | 26,730,899 | 17·292 | 6·687 |
| 300 | 942·48 | 70685·83 | 90,000 | 27,000,000 | 17·320 | 6·694 |
| 301 | 945·62 | 71157·86 | 90,601 | 27,270,901 | 17·349 | 6·702 |
| 302 | 948·76 | 71631·45 | 91,204 | 27,543,608 | 17·378 | 6·709 |
| 303 | 951·90 | 72106·62 | 91,809 | 27,818,127 | 17·407 | 6·717 |
| 304 | 955·04 | 72583·36 | 92,416 | 28,094,464 | 17·436 | 6·724 |
| 305 | 958·19 | 73061·66 | 93,025 | 28,372,625 | 17·464 | 6·731 |
| 306 | 961·33 | 73541·54 | 93,636 | 28,652,616 | 17·493 | 6·739 |
| 307 | 964·47 | 74022·99 | 94,249 | 28,934,443 | 17·521 | 6·746 |
| 308 | 967·61 | 74506·01 | 94,864 | 29,218,112 | 17·549 | 6·753 |
| 309 | 970·75 | 74990·60 | 95,481 | 29,503,629 | 17·578 | 6·761 |
| 310 | 973·89 | 75476·76 | 96,100 | 29,791,000 | 17·607 | 6·768 |
| 311 | 977·03 | 75964·50 | 96,721 | 30,080,231 | 17·635 | 6·775 |
| 312 | 980·18 | 76453·80 | 97,344 | 30,371,328 | 17·663 | 6·782 |
| 313 | 983·32 | 76944·67 | 97,969 | 30,664.297 | 17·692 | 6·789 |
| 314 | 986·46 | 77437·12 | 98,596 | 30,959,144 | 17·720 | 6·797 |
| 315 | 989·60 | 77931·13 | 99,225 | 31,255,875 | 17·748 | 6·804 |
| 316 | 992·74 | 78426·72 | 99,856 | 31,554,496 | 17·776 | 6·811 |
| 317 | 995·88 | 78923·88 | 100,489 | 31,855,013 | 17·804 | 6·818 |
| 318 | 999·03 | 79422·60 | 101,124 | 32,157,432 | 17·832 | 6·826 |
| 319 | 1002·17 | 79922·90 | 101,761 | 32,461,759 | 17·860 | 6·833 |
| 320 | 1005·31 | 80424·77 | 102,400 | 32,768,000 | 17·888 | 6·839 |
| 321 | 1008·45 | 80928·21 | 103,041 | 33,076,161 | 17·916 | 6·847 |
| 322 | 1011·59 | 81433·22 | 103,684 | 33,386,248 | 17·944 | 6·854 |
| 323 | 1014·73 | 81939·80 | 104,329 | 33,698,267 | 17·972 | 6·861 |
| 324 | 1017·88 | 82447·96 | 104,976 | 34,012,224 | 18·000 | 6·868 |
| 325 | 1021·02 | 82957·68 | 105,625 | 34,328,125 | 18·028 | 6·875 |
| 326 | 1024·16 | 83468·98 | 106,276 | 34,645,976 | 18·055 | 6·882 |
| 327 | 1027·30 | 83981·84 | 106,929 | 34,965,783 | 18·083 | 6·889 |
| 328 | 1030·44 | 84496·28 | 107,584 | 35,287,552 | 18·111 | 6·896 |
| 329 | 1033·58 | 85012·28 | 108,241 | 35,611,289 | 18·138 | 6·903 |
| 330 | 1036·73 | 85529·86 | 108,900 | 35,937,000 | 18·166 | 6·910 |
| 331 | 1039·87 | 86049·01 | 109,561 | 36,264,691 | 18·193 | 6·917 |
| 332 | 1043·01 | 86569·73 | 110,224 | 36,594,368 | 18·221 | 6·924 |
| 333 | 1046·15 | 87092·02 | 110,889 | 36,926,037 | 18·248 | 6·931 |

| No. or Diam. | Circum-ference. | Circular Area. | Square. | Cube. | Square Root. | Cube Root. |
|---|---|---|---|---|---|---|
| **334** | 1049·29 | 87615·88 | 111,556 | 37,259,704 | 18·276 | 6·938 |
| **335** | 1052·43 | 88141·31 | 112,225 | 37,595,375 | 18·303 | 6·945 |
| **336** | 1055·57 | 88668·31 | 112,896 | 37,933,056 | 18·330 | 6·952 |
| **337** | 1058·72 | 89196·88 | 113,569 | 38,272,753 | 18·357 | 6·959 |
| **338** | 1061·86 | 89727·03 | 114,244 | 38,614,472 | 18·385 | 6·965 |
| **339** | 1065·00 | 90258·74 | 114,921 | 38,958,219 | 18·412 | 6·973 |
| **340** | 1068·14 | 90792·03 | 115,600 | 39,304,000 | 18·439 | 6·979 |
| **341** | 1071·28 | 91326·88 | 116,281 | 39,651,821 | 18·466 | 6·986 |
| **342** | 1074·42 | 91863·31 | 116,964 | 40,001,688 | 18·493 | 6·993 |
| **343** | 1077·57 | 92401·31 | 117,649 | 40,353,607 | 18·520 | 7·000 |
| **344** | 1080·71 | 92940·88 | 118,336 | 40,707,584 | 18·547 | 7·007 |
| **345** | 1083·85 | 93482·02 | 119,025 | 41,063,625 | 18·574 | 7·014 |
| **346** | 1086·99 | 94024·73 | 119,716 | 41,421,736 | 18·601 | 7·020 |
| **347** | 1090·13 | 94569·01 | 120,409 | 41,781,923 | 18·628 | 7·027 |
| **348** | 1093·27 | 95114·86 | 121,104 | 42,144,192 | 18·655 | 7·034 |
| **349** | 1096·42 | 95662·28 | 121,801 | 42,508,549 | 18·681 | 7·040 |
| **350** | 1099·56 | 96211·28 | 122,500 | 42,875,000 | 18·708 | 7·047 |
| **351** | 1102·70 | 96761·84 | 123,201 | 43,243,551 | 18·735 | 7·054 |
| **352** | 1105·84 | 97314·76 | 123,904 | 43,614,208 | 18·762 | 7·061 |
| **353** | 1108·98 | 97867·68 | 124,609 | 43,986,977 | 16·788 | 7·067 |
| **354** | 1112·12 | 98422·96 | 125,316 | 44,361,864 | 18·815 | 7·074 |
| **355** | 1115·26 | 98979·80 | 126,025 | 44,738,875 | 18·842 | 7·081 |
| **356** | 1118·41 | 99538·22 | 126,736 | 45,118,016 | 18·868 | 7·087 |
| **357** | 1121·55 | 100098·21 | 127,449 | 45,499,293 | 18·894 | 7·094 |
| **358** | 1124·69 | 100659·27 | 128,164 | 45,882,712 | 18·921 | 7·101 |
| **359** | 1127·83 | 101222·90 | 128,881 | 46,268,279 | 18·947 | 7·107 |
| **360** | 1130·97 | 101787·60 | 129,600 | 46,656,000 | 18·974 | 7·114 |
| **361** | 1134·11 | 102353·87 | 130,321 | 47,045,881 | 19·000 | 7·120 |
| **362** | 1137·26 | 102921·72 | 131,044 | 47,437,928 | 19·026 | 7·127 |
| **363** | 1140·40 | 103491·13 | 131,769 | 47,832,147 | 19·052 | 7·133 |
| **364** | 1143·54 | 104062·12 | 132,496 | 48,228,544 | 19·079 | 7·140 |
| **365** | 1146·68 | 104634·67 | 133,225 | 48,627,125 | 19·105 | 7·146 |
| **366** | 1149·82 | 105208·80 | 133,956 | 49,027,896 | 19·131 | 7·153 |
| **367** | 1152·96 | 105784·49 | 134,689 | 49,430,863 | 19·157 | 7·159 |
| **368** | 1156·11 | 106361·76 | 135,424 | 49,836,032 | 19·183 | 7·166 |
| **369** | 1159·25 | 106940·60 | 136,161 | 50,243,409 | 19·209 | 7·172 |
| **370** | 1162·39 | 107521·01 | 136,900 | 50,653,000 | 19·235 | 7·179 |
| **371** | 1165·53 | 108102·99 | 137,641 | 51,064,811 | 19·261 | 7·185 |
| **372** | 1168·67 | 108686·54 | 138,384 | 51,478,848 | 19·287 | 7·192 |
| **373** | 1171·81 | 109271·66 | 139,129 | 51,895,117 | 19·313 | 7·198 |
| **374** | 1174·96 | 109858·35 | 139,876 | 52,313,624 | 19·339 | 7·205 |
| **375** | 1178·10 | 110446·62 | 140,625 | 52,734,375 | 19·365 | 7·211 |

| No. or Diam. | Circumference. | Circular Area. | Square. | Cube. | Square Root. | Cube Root. |
|---|---|---|---|---|---|---|
| 376 | 1181·24 | 111036·45 | 141,376 | 53,157,376 | 19·391 | 7·218 |
| 377 | 1184·38 | 111627·86 | 142,129 | 53,582,633 | 19·416 | 7·224 |
| 378 | 1187·52 | 112220·83 | 142,884 | 54,010,152 | 19·442 | 7·230 |
| 379 | 1190·66 | 112815·38 | 143,641 | 54,439,939 | 19·468 | 7·237 |
| 380 | 1193·80 | 113411·49 | 144,400 | 54,872,000 | 19·493 | 7·243 |
| 381 | 1196·95 | 114009·18 | 145,161 | 55,306,341 | 19·519 | 7·249 |
| 382 | 1200·09 | 114608·44 | 145,924 | 55,742,968 | 19·545 | 7·256 |
| 383 | 1203·23 | 115209·27 | 146,689 | 56,181,887 | 19·570 | 7·262 |
| 384 | 1206·37 | 115811·67 | 147,456 | 56,623,104 | 19·596 | 7·268 |
| 385 | 1209·51 | 116415·64 | 148,225 | 57,066,625 | 19·621 | 7·275 |
| 386 | 1212·65 | 117021·18 | 148,996 | 57,512,456 | 19·647 | 7·281 |
| 387 | 1215·80 | 117628·30 | 149,769 | 57,960,603 | 19·672 | 7·287 |
| 388 | 1218·94 | 118236·98 | 150,544 | 58,411,072 | 19·698 | 7·294 |
| 389 | 1222·08 | 118847·24 | 151,321 | 58,863,869 | 19·723 | 7·299 |
| 390 | 1225·22 | 119459·06 | 152,100 | 59,319,000 | 19·748 | 7·306 |
| 391 | 1228·36 | 120072·46 | 152,881 | 59,776,471 | 19·774 | 7·312 |
| 392 | 1231·50 | 120687·42 | 153,664 | 60,236,288 | 19·799 | 7·319 |
| 393 | 1234·65 | 121303·96 | 154,449 | 60,698,457 | 19·824 | 7·325 |
| 394 | 1237·79 | 121922·07 | 155,236 | 61,162,984 | 19·849 | 7·331 |
| 395 | 1240·93 | 122541·75 | 156,025 | 61,629,875 | 19·875 | 7·337 |
| 396 | 1244·07 | 123163·00 | 156,816 | 62,099,136 | 19·899 | 7·343 |
| 397 | 1247·21 | 123785·82 | 157,609 | 62,570,773 | 19·925 | 7·349 |
| 398 | 1250·35 | 124410·21 | 158,404 | 63,044,792 | 19·949 | 7·356 |
| 399 | 1253·49 | 125036·17 | 159,201 | 63,521,199 | 19·975 | 7·362 |
| 400 | 1256·64 | 125663·71 | 160,000 | 64,000,000 | 20·000 | 7·368 |
| 401 | 1259·78 | 126292·81 | 160,801 | 64,481,201 | 20·025 | 7·374 |
| 402 | 1262·92 | 126923·48 | 161,604 | 64,964,808 | 20·049 | 7·380 |
| 403 | 1266·06 | 127555·73 | 162,409 | 65,450,827 | 20·075 | 7·386 |
| 404 | 1269·20 | 128189·55 | 163,216 | 65,939,264 | 20·099 | 7·392 |
| 405 | 1272·34 | 128824·93 | 164,025 | 66,430,125 | 20·125 | 7·399 |
| 406 | 1275·49 | 129461·89 | 164,836 | 66,923,416 | 20·149 | 7·405 |
| 407 | 1278·63 | 130100·42 | 165,649 | 67,419,143 | 20·174 | 7·411 |
| 408 | 1281·77 | 130740·52 | 166,464 | 67,911,312 | 20·199 | 7·417 |
| 409 | 1284·91 | 131382·19 | 167,281 | 68,417,929 | 20·224 | 7·422 |
| 410 | 1288·05 | 132025·43 | 168,100 | 68,921,000 | 20·248 | 7·429 |
| 411 | 1291·19 | 132670·24 | 168,921 | 69,426,531 | 20·273 | 7·434 |
| 412 | 1294·34 | 133316·63 | 169,744 | 69,934,528 | 20·298 | 7·441 |
| 413 | 1297·48 | 133964·58 | 170,569 | 70,444,997 | 20·322 | 7·447 |
| 414 | 1300·62 | 134614·10 | 171,396 | 70,957,944 | 20·347 | 7·453 |
| 415 | 1303·76 | 135265·20 | 172,225 | 71,473,375 | 20·371 | 7·459 |
| 416 | 1306·90 | 135917·86 | 173,056 | 71,991,296 | 20·396 | 7·465 |
| 417 | 1310·04 | 136572·10 | 173,889 | 72,511,713 | 20·421 | 7·471 |

| No. or Diam. | Circumference. | Circular Area. | Square. | Cube. | Square Root. | Cube Root. |
|---|---|---|---|---|---|---|
| 418 | 1313·19 | 137227·91 | 174,724 | 73,034,632 | 20·445 | 7·477 |
| 419 | 1316·33 | 137885·29 | 175,561 | 73,560,059 | 20·469 | 7·483 |
| 420 | 1319·47 | 138544·24 | 176,400 | 74,088,000 | 20·494 | 7·489 |
| 421 | 1322·61 | 139204·70 | 177,241 | 74,618,461 | 20·518 | 7·495 |
| 422 | 1325·75 | 139866·85 | 178,084 | 75,151,448 | 20·543 | 7·501 |
| 423 | 1328·89 | 140530·51 | 178,929 | 75,686,967 | 20·567 | 7·507 |
| 424 | 1332·03 | 141195·74 | 179,776 | 76,225,024 | 20·591 | 7·513 |
| 425 | 1335·18 | 141862·54 | 180,625 | 76,765,625 | 20·615 | 7·518 |
| 426 | 1338·32 | 142530·92 | 181,476 | 77,308,776 | 20·639 | 7·524 |
| 427 | 1341·46 | 143200·86 | 182,329 | 77,854,483 | 20·664 | 7·530 |
| 428 | 1344·60 | 143872·38 | 183,184 | 78,402,752 | 20·688 | 7·536 |
| 429 | 1347·74 | 144545·46 | 184,041 | 78,953,589 | 20·712 | 7·542 |
| 430 | 1550·88 | 145220·12 | 184,900 | 79,507,000 | 20·736 | 7·548 |
| 431 | 1354·03 | 145896·35 | 185,761 | 80,062,991 | 20·760 | 7·554 |
| 432 | 1357·17 | 146574·15 | 186,624 | 80,621,568 | 20·785 | 7·559 |
| 433 | 1360·31 | 147253·52 | 187,489 | 81,182,737 | 20·809 | 7·565 |
| 434 | 1363·45 | 147934·46 | 188,356 | 81,746,504 | 20·833 | 7·571 |
| 435 | 1366·59 | 148616·97 | 189,225 | 82,312,875 | 20·857 | 7·577 |
| 436 | 1369·73 | 149301·05 | 190,096 | 82,881,856 | 20·881 | 7·583 |
| 437 | 1372·88 | 149986·70 | 190,969 | 83,453,453 | 20·904 | 7·588 |
| 438 | 1376·02 | 150673·93 | 191,844 | 84,027,672 | 20·928 | 7·594 |
| 439 | 1379·16 | 151362·72 | 192,721 | 84,604,519 | 20·952 | 7·600 |
| 440 | 1382·30 | 152053·08 | 193,600 | 85,184,000 | 20·976 | 7·606 |
| 441 | 1385·44 | 152745·02 | 194,481 | 85,766,121 | 21·000 | 7·612 |
| 442 | 1388·58 | 153438·53 | 195,364 | 86,350,388 | 21·024 | 7·617 |
| 443 | 1391·73 | 154133·60 | 196,249 | 86,938,307 | 21·047 | 7·623 |
| 444 | 1394·87 | 154830·25 | 197,136 | 87,528,384 | 21·071 | 7·629 |
| 445 | 1398·01 | 155528·47 | 198,025 | 88,121,125 | 21·095 | 7·635 |
| 446 | 1401·15 | 156228·26 | 198,916 | 88,716,536 | 21·119 | 7·640 |
| 447 | 1404·29 | 156929·62 | 199,809 | 89,314,623 | 21·142 | 7·646 |
| 448 | 1407·43 | 157632·55 | 200,704 | 89,915,392 | 21·166 | 7·652 |
| 449 | 1410·57 | 158337·06 | 201,601 | 90,518,849 | 21·189 | 7·657 |
| 450 | 1413·72 | 159043·13 | 202,500 | 91,125,000 | 21·213 | 7·663 |
| 451 | 1416·86 | 159750·77 | 203,401 | 91,733,851 | 21·237 | 7·669 |
| 452 | 1420·00 | 160459·99 | 204,304 | 92,345,408 | 21·260 | 7·674 |
| 453 | 1423·14 | 161170·77 | 205,209 | 92,959,677 | 21·284 | 7·680 |
| 454 | 1426·28 | 161883·13 | 206,106 | 93,576,664 | 21·307 | 7·686 |
| 455 | 1429·42 | 162597·06 | 207,025 | 94,196,375 | 21·331 | 7·691 |
| 456 | 1432·57 | 163312·55 | 207,936 | 94,818,816 | 21·354 | 7·697 |
| 457 | 1435·71 | 164029·62 | 208,849 | 95,443,993 | 21·377 | 7·703 |
| 458 | 1438·85 | 164748·26 | 209,764 | 96,071,912 | 21·401 | 7·708 |
| 459 | 1441·99 | 165468·47 | 210,681 | 96,702,579 | 21·424 | 7·714 |

| No. or Diam. | Circumference. | Circular Area. | Square. | Cube. | Square Root. | Cube Root. |
|---|---|---|---|---|---|---|
| **460** | 1445·13 | 166190·25 | 211,600 | 97,336,000 | 21·447 | 7·719 |
| **461** | 1448·27 | 166913·60 | 212,521 | 97,972,181 | 21·471 | 7·725 |
| **462** | 1451·42 | 167638·53 | 213,444 | 98,611,128 | 21·494 | 7·731 |
| **463** | 1454·56 | 168365·02 | 214,369 | 99,252,847 | 21·517 | 7·736 |
| **464** | 1457·70 | 169093·08 | 215,296 | 99,897,345 | 21·541 | 7·742 |
| **465** | 1460·84 | 169822·72 | 216,225 | 100,544,625 | 21·564 | 7·747 |
| **466** | 1463·98 | 170553·92 | 217,156 | 101,194,696 | 21·587 | 7·753 |
| **467** | 1467·12 | 171286·70 | 218,089 | 101,847,563 | 21·610 | 7·758 |
| **468** | 1470·26 | 172021·05 | 219,024 | 102,503,232 | 21·633 | 7·764 |
| **469** | 1473·41 | 172756·97 | 219,961 | 103,161,709 | 21·656 | 7·769 |
| **470** | 1476·55 | 173494·45 | 220,900 | 103,823,000 | 21·679 | 7·775 |
| **471** | 1479·69 | 174233·51 | 221,841 | 104,487,111 | 21·702 | 7·780 |
| **472** | 1482·83 | 174974·14 | 222,784 | 105,154,048 | 21·725 | 7·786 |
| **473** | 1485·97 | 175716·35 | 223,729 | 105,823,817 | 21·749 | 7·791 |
| **474** | 1489·11 | 176460·12 | 224,676 | 106,496,424 | 21·771 | 7·797 |
| **475** | 1492·26 | 177205·46 | 225,625 | 107,171,875 | 21·794 | 7·802 |
| **476** | 1495·40 | 177952·37 | 226,576 | 107,850,176 | 21·817 | 7·808 |
| **477** | 1498·54 | 178700·86 | 227,529 | 108,531,333 | 21·840 | 7·813 |
| **478** | 1501·68 | 179450·91 | 228,484 | 109,215,352 | 21·863 | 7·819 |
| **479** | 1504·82 | 180202·54 | 229,441 | 109,902,239 | 21·886 | 7·824 |
| **480** | 1507·96 | 180955·74 | 230,400 | 110,592,000 | 21·909 | 7·830 |
| **481** | 1511·11 | 181710·50 | 231,361 | 111,284,641 | 21·932 | 7·835 |
| **482** | 1514·25 | 182466·84 | 232,324 | 111,980,168 | 21·954 | 7·840 |
| **483** | 1517·39 | 183224·75 | 233,289 | 112,678,587 | 21·977 | 7·846 |
| **484** | 1520·53 | 183984·23 | 234,256 | 113,379,904 | 22·000 | 7·851 |
| **485** | 1523·67 | 184745·28 | 235,225 | 114,084,125 | 22·023 | 7·857 |
| **486** | 1526·81 | 185507·90 | 236,196 | 114,791,256 | 22·045 | 7·862 |
| **487** | 1529·96 | 186272·10 | 237,169 | 115,501,303 | 22·069 | 7·868 |
| **488** | 1533·10 | 187037·86 | 238,144 | 116,214,272 | 22·091 | 7·873 |
| **489** | 1536·24 | 187805·19 | 239,121 | 116,936,169 | 22·113 | 7·878 |
| **490** | 1539·38 | 188574·10 | 240,100 | 117,649,000 | 22·136 | 7·884 |
| **491** | 1542·52 | 189344·57 | 241,081 | 118,370,771 | 22·158 | 7·889 |
| **492** | 1545·66 | 190116·62 | 242,064 | 119,095,488 | 22·181 | 7·894 |
| **493** | 1548·80 | 190890·24 | 243,049 | 119,823,157 | 22·204 | 7·899 |
| **494** | 1551·95 | 191665·43 | 244,036 | 120,553,784 | 22·226 | 7·905 |
| **495** | 1555·09 | 192442·19 | 245,025 | 121,287,375 | 22·248 | 7·910 |
| **496** | 1558·23 | 193220·51 | 246,016 | 122,023,936 | 22·271 | 7·915 |
| **497** | 1561·37 | 194000·42 | 247,009 | 122,763,473 | 22·293 | 7·921 |
| **498** | 1564·51 | 194781·89 | 248,004 | 123,505,992 | 22·316 | 7·926 |
| **499** | 1567·65 | 195564·93 | 249,001 | 124,251,499 | 22·338 | 7·932 |
| **500** | 1570·80 | 196349·54 | 250,000 | 125,000,000 | 22·361 | 7·937 |
| **501** | 1573·94 | 197135·72 | 251,001 | 125,751,501 | 22·383 | 7·942 |

| No. or Diam. | Circumference. | Circular Area. | Square. | Cube. | Square Root. | Cube Root. |
|---|---|---|---|---|---|---|
| 502 | 1577·08 | 197923·48 | 252,004 | 126,506,008 | 22·405 | 7·947 |
| 503 | 1580·22 | 198712·80 | 253,009 | 127,263,527 | 22·428 | 7·953 |
| 504 | 1583·36 | 199503·70 | 254,016 | 128,024,864 | 22·449 | 7·958 |
| 505 | 1586·50 | 200296·17 | 255,025 | 128,787,625 | 22·472 | 7·963 |
| 506 | 1589·65 | 201090·20 | 256,036 | 129,554,216 | 22·494 | 7·969 |
| 507 | 1592·79 | 201885·81 | 257,049 | 130,323,843 | 22·517 | 7·974 |
| 508 | 1595·93 | 202682·99 | 258,064 | 131,096,512 | 22·539 | 7·979 |
| 509 | 1599·07 | 203481·74 | 259,081 | 131,872,229 | 22·561 | 7·984 |
| 510 | 1602·21 | 204282·06 | 260,100 | 132,651,000 | 22·583 | 7·989 |
| 511 | 1605·35 | 205083·95 | 261,121 | 133,432,831 | 22·605 | 7·995 |
| 512 | 1608·49 | 205887·42 | 262,144 | 134,217,728 | 22·627 | 8·000 |
| 513 | 1611·64 | 206692·45 | 263,169 | 135,005,697 | 22·649 | 8·005 |
| 514 | 1614·78 | 207499·05 | 264,196 | 135,796,744 | 22·671 | 8·010 |
| 515 | 1617·92 | 208307·23 | 265,225 | 136,590,875 | 22·694 | 8·016 |
| 516 | 1621·06 | 209116·97 | 266,256 | 137,388,096 | 22·716 | 8·021 |
| 517 | 1624·20 | 209928·29 | 267,289 | 138,188,413 | 22·738 | 8·026 |
| 518 | 1627·34 | 210741·18 | 268,324 | 138,991,832 | 22·759 | 8·031 |
| 519 | 1630·49 | 211555·63 | 269,361 | 139,798,359 | 22·782 | 8·036 |
| 520 | 1633·63 | 212371·66 | 270,400 | 140,608,000 | 22·803 | 8·041 |
| 521 | 1636·77 | 213189·26 | 271,441 | 141,420,761 | 22·825 | 8·047 |
| 522 | 1639·91 | 214008·43 | 272,484 | 142,236,648 | 22·847 | 8·052 |
| 523 | 1643·05 | 214829·17 | 273,529 | 143,055,667 | 22·869 | 8·057 |
| 524 | 1646·19 | 215651·49 | 274,576 | 143,877,824 | 22·891 | 8·062 |
| 525 | 1649·34 | 216475·37 | 275,625 | 144,703,125 | 22·913 | 8·067 |
| 526 | 1652·48 | 217300·82 | 276,676 | 145,531,576 | 22·935 | 8·072 |
| 527 | 1655·62 | 218127·85 | 277,729 | 146,363,183 | 22·956 | 8·077 |
| 528 | 1658·76 | 218956·44 | 278,784 | 147,197,952 | 22·978 | 8·082 |
| 529 | 1661·90 | 219786·61 | 279,841 | 148,035,889 | 23·000 | 8·087 |
| 530 | 1665·04 | 220618·32 | 280,900 | 148,877,000 | 23·022 | 8·093 |
| 531 | 1668·19 | 221451·65 | 281,961 | 149,721,291 | 23·043 | 8·098 |
| 532 | 1671·33 | 222286·53 | 283,024 | 150,568,768 | 23·065 | 8·103 |
| 533 | 1674·47 | 223122·98 | 284,089 | 151,419,437 | 23·087 | 8·108 |
| 534 | 1677·61 | 223961·00 | 285,156 | 152,273,304 | 23·108 | 8·113 |
| 535 | 1680·75 | 224800·59 | 286,225 | 153,130,375 | 23·130 | 8·118 |
| 536 | 1683·89 | 225641·75 | 287,296 | 153,990,656 | 23·152 | 8·123 |
| 537 | 1687·04 | 226484·48 | 288,369 | 154,854,153 | 23·173 | 8·128 |
| 538 | 1690·18 | 227328·77 | 289,444 | 155,720,872 | 23·195 | 8·133 |
| 539 | 1693·32 | 228174·66 | 290,521 | 156,590,819 | 23·216 | 8·138 |
| 540 | 1696·46 | 229022·10 | 291,600 | 157,464,000 | 23·238 | 8·143 |
| 541 | 1699·60 | 229871·12 | 292,681 | 158,340,421 | 23·259 | 8·148 |
| 542 | 1702·74 | 230721·71 | 293,764 | 159,220,088 | 23·281 | 8·153 |
| 543 | 1705·88 | 231573·86 | 294,849 | 160,103,007 | 23·302 | 8·158 |

| No. or Diam. | Circumference | Circular Area. | Square. | Cube. | Square Root. | Cube Root. |
|---|---|---|---|---|---|---|
| **544** | 1709·03 | 232427·59 | 295,936 | 160,989,184 | 23·324 | 8·163 |
| **545** | 1712·17 | 233282·89 | 297,025 | 161,878,625 | 23·345 | 8·168 |
| **546** | 1715·31 | 234139·76 | 298,116 | 162,771,336 | 23·367 | 8·173 |
| **547** | 1718·45 | 234998·20 | 299,209 | 163,667,323 | 23·388 | 8·178 |
| **548** | 1721·59 | 235858·21 | 300,304 | 164,566,592 | 23·409 | 8·183 |
| **549** | 1724·73 | 236719·79 | 301,401 | 165,469,149 | 23·431 | 8·188 |
| **550** | 1727·88 | 237582·94 | 302,500 | 166,375,000 | 23·452 | 8·193 |
| **551** | 1731·02 | 238447·67 | 303,601 | 167,284,151 | 23·473 | 8·198 |
| **552** | 1734·16 | 239313·96 | 304,704 | 168,196,608 | 23·495 | 8·203 |
| **553** | 1737·30 | 240181·83 | 305,809 | 169,112,377 | 23·516 | 8·208 |
| **554** | 1740·44 | 241051·26 | 306,916 | 170,031,464 | 23·537 | 8·213 |
| **555** | 1743·58 | 241922·27 | 308,025 | 170,953,875 | 23·558 | 8·218 |
| **556** | 1746·73 | 242794·85 | 309,136 | 171,879,616 | 23·579 | 8·223 |
| **557** | 1749·87 | 243668·99 | 310,249 | 172,808,693 | 23·601 | 8·228 |
| **558** | 1753·00 | 244544·61 | 311,364 | 173,741,112 | 23·622 | 8·233 |
| **559** | 1756·15 | 245422·00 | 312,481 | 174,676,879 | 23·643 | 8·238 |
| **560** | 1759·29 | 246300·86 | 313,600 | 175,616,000 | 23·664 | 8·242 |
| **561** | 1762·43 | 247181·30 | 314,721 | 176,558,481 | 23·685 | 8·247 |
| **562** | 1765·57 | 248062·30 | 315,844 | 177,504,328 | 23·706 | 8·252 |
| **563** | 1768·72 | 248946·87 | 316,969 | 178,453,547 | 23·728 | 8·257 |
| **564** | 1771·86 | 249832·01 | 318,096 | 179,406,144 | 23·749 | 8·262 |
| **565** | 1775·00 | 250718·73 | 319,225 | 180,362,125 | 23·769 | 8·267 |
| **566** | 1778·14 | 251607·01 | 320,356 | 181,321,496 | 23·791 | 8·272 |
| **567** | 1781·28 | 252496·87 | 321,489 | 182,284,263 | 23·812 | 8·277 |
| **568** | 1784·42 | 253388·30 | 322,624 | 183,250,432 | 23·833 | 8·282 |
| **569** | 1787·57 | 254281·30 | 323,761 | 184,220,009 | 23·854 | 8·286 |
| **570** | 1790·71 | 255175·86 | 324,900 | 185,193,000 | 23·875 | 8·291 |
| **571** | 1793·85 | 256072·00 | 326,041 | 186,169,411 | 23·896 | 8·296 |
| **572** | 1796·99 | 256969·71 | 327,184 | 187,149,248 | 23·916 | 8·301 |
| **573** | 1800·13 | 257868·99 | 328,329 | 188,132,517 | 23·937 | 8·306 |
| **574** | 1803·27 | 258769·85 | 329,476 | 189,119,224 | 23·958 | 8·311 |
| **575** | 1806·42 | 259672·27 | 330,625 | 190,109,375 | 23·979 | 8·315 |
| **576** | 1809·56 | 260576·26 | 331,776 | 191,102,976 | 24·000 | 8·320 |
| **577** | 1812·70 | 261481·83 | 332,929 | 192,100,033 | 24·021 | 8·325 |
| **578** | 1815·84 | 262388·96 | 334,084 | 193,100,552 | 24·042 | 8·330 |
| **579** | 1818·98 | 263297·67 | 335,241 | 194,104,539 | 24·062 | 8·335 |
| **580** | 1822·12 | 264207·94 | 336,400 | 195,112,000 | 24·083 | 8·339 |
| **581** | 1825·26 | 265119·79 | 337,561 | 196,122,941 | 24·104 | 8·344 |
| **582** | 1828·41 | 266033·21 | 338,724 | 197,137,368 | 24·125 | 8·349 |
| **583** | 1831·55 | 266948·20 | 339,889 | 198,155,287 | 24·145 | 8·354 |
| **584** | 1834·69 | 267864·76 | 341,056 | 199,176,704 | 24·166 | 8·359 |
| **585** | 1837·83 | 268782·80 | 342,225 | 200,201,625 | 24·187 | 8·363 |

| No. or Diam. | Circumference. | Circular Area. | Square. | Cube. | Square Root. | Cube Root. |
|---|---|---|---|---|---|---|
| 586 | 1840·97 | 269702·59 | 343,396 | 201,230,056 | 24·207 | 8·368 |
| 587 | 1844·11 | 270623·86 | 344,569 | 202,262,003 | 24·228 | 8·373 |
| 588 | 1847·26 | 271546·70 | 345,744 | 203,297,472 | 24·249 | 8·378 |
| 589 | 1850·40 | 272471·12 | 346,921 | 204,336,469 | 24·269 | 8·382 |
| 590 | 1853·54 | 273397·10 | 348,100 | 205,379,000 | 24·289 | 8·387 |
| 591 | 1856·68 | 274324·66 | 349,281 | 206,425,071 | 24·310 | 8·392 |
| 592 | 1859·82 | 275253·78 | 350,464 | 207,474,688 | 24·331 | 8·397 |
| 593 | 1862·96 | 276184·48 | 351,649 | 208,527,857 | 24·351 | 8·401 |
| 594 | 1866·11 | 277116·75 | 352,836 | 209,584,584 | 24·372 | 8·406 |
| 595 | 1869·25 | 278050·59 | 354,025 | 210,644,875 | 24·393 | 8·411 |
| 596 | 1872·39 | 278985·99 | 355,216 | 211,708,736 | 24·413 | 8·415 |
| 597 | 1875·53 | 279922·97 | 356,409 | 212,776,173 | 24·433 | 8·420 |
| 598 | 1878·67 | 280861·53 | 357,604 | 213,847,192 | 24·454 | 8·425 |
| 599 | 1881·81 | 281801·65 | 358,801 | 214,921,799 | 24·474 | 8·429 |
| 600 | 1884·96 | 282743·34 | 360,000 | 216,000,000 | 24·495 | 8·434 |
| 601 | 1888·10 | 283686·60 | 361,201 | 217,081,801 | 24·515 | 8·439 |
| 602 | 1891·24 | 284631·44 | 362,404 | 218,167,208 | 24·536 | 8·444 |
| 603 | 1894·38 | 285577·84 | 363,609 | 219,256,227 | 24·556 | 8·448 |
| 604 | 1897·52 | 286525·82 | 364,816 | 220,348,864 | 24·576 | 8·453 |
| 605 | 1900·66 | 287475·36 | 366,025 | 221,445,125 | 24·597 | 8·458 |
| 606 | 1903·80 | 288426·48 | 367,236 | 222,545,016 | 24·617 | 8·462 |
| 607 | 1906·95 | 289379·17 | 368,449 | 223,648,543 | 24·637 | 8·467 |
| 608 | 1910·09 | 290333·43 | 369,664 | 224,755,712 | 24·658 | 8·472 |
| 609 | 1913·23 | 291289·26 | 370,881 | 225,866,529 | 24·678 | 8·476 |
| 610 | 1916·37 | 292246·66 | 372,100 | 226,981,000 | 24·698 | 8·481 |
| 611 | 1919·51 | 293205·63 | 373,321 | 228,099,131 | 24·718 | 8·485 |
| 612 | 1922·65 | 294166·17 | 374,544 | 229,220,928 | 24·739 | 8·490 |
| 613 | 1925·80 | 295128·28 | 375,769 | 230,346,397 | 24·758 | 8·495 |
| 614 | 1928·94 | 296091·97 | 376,996 | 231,475,544 | 24·779 | 8·499 |
| 615 | 1932·08 | 297057·22 | 378,225 | 232,608,375 | 24·799 | 8·504 |
| 616 | 1935·22 | 298024·05 | 379,456 | 233,744,896 | 24·819 | 8·509 |
| 617 | 1938·36 | 298992·44 | 380,689 | 234,885,113 | 24·839 | 8·513 |
| 618 | 1941·50 | 299962·41 | 381,924 | 236,029,032 | 24·859 | 8·518 |
| 619 | 1944·65 | 300933·95 | 383,161 | 237,176,659 | 24·879 | 8·522 |
| 620 | 1947·79 | 301907·05 | 384,400 | 238,628,000 | 24·899 | 8·527 |
| 621 | 1950·93 | 302881·73 | 385,641 | 239,483,061 | 24·919 | 8·532 |
| 622 | 1954·07 | 303857·98 | 386,884 | 240,641,848 | 24·939 | 8·536 |
| 623 | 1957·21 | 304835·80 | 388,129 | 241,804,367 | 24·959 | 8·541 |
| 624 | 1960·35 | 305815·20 | 389,376 | 242,970,624 | 24·980 | 8·545 |
| 625 | 1963·50 | 306796·16 | 390,625 | 244,140,625 | 25·000 | 8·549 |
| 626 | 1966·64 | 307778·69 | 391,876 | 245,314,376 | 25·019 | 8·554 |
| 627 | 1969·78 | 308762·79 | 393,129 | 246,491,883 | 25·040 | 8·559 |

| No. or Diam. | Circumference. | Circular Area. | Square. | Cube. | Square Root. | Cube Root. |
|---|---|---|---|---|---|---|
| 628 | 1972·92 | 309748·47 | 394,384 | 247,673,152 | 25·059 | 8·563 |
| 629 | 1976·06 | 310735·71 | 395,641 | 248,858,189 | 25·079 | 8·568 |
| 630 | 1979·20 | 311724·53 | 396,900 | 250,047,000 | 25·099 | 8·573 |
| 631 | 1982·34 | 312714·92 | 398,161 | 251,239,591 | 25·119 | 8·577 |
| 632 | 1985·49 | 313706·88 | 399,424 | 252,435,968 | 25·139 | 8·582 |
| 633 | 1988·63 | 314700·40 | 400,689 | 253,636,137 | 25·159 | 8·586 |
| 634 | 1991·77 | 315695·50 | 401,956 | 254,840,104 | 25·179 | 8·591 |
| 635 | 1994·91 | 316692·17 | 403,225 | 256,047,875 | 25·199 | 8·595 |
| 636 | 1998·05 | 317690·42 | 404,496 | 257,259,456 | 25·219 | 8·599 |
| 637 | 2001·19 | 318690·23 | 405,769 | 258,474,853 | 25·239 | 8·604 |
| 638 | 2004·34 | 319691·61 | 407,044 | 259,694,072 | 25·259 | 8·609 |
| 639 | 2007·48 | 320694·56 | 408,321 | 260,917,119 | 25·278 | 8·613 |
| 640 | 2010·62 | 321699·09 | 409,600 | 262,144,000 | 25·298 | 8·618 |
| 641 | 2013·76 | 322705·18 | 410,881 | 263,374,721 | 25·318 | 8·622 |
| 642 | 2016·90 | 323712·85 | 412,164 | 264,609,288 | 25·338 | 8·627 |
| 643 | 2020·04 | 324722·09 | 413,449 | 265,847,707 | 25·357 | 8·631 |
| 644 | 2023·19 | 325732·89 | 414,736 | 267,089,984 | 25·377 | 8·636 |
| 645 | 2026·33 | 326745·27 | 416,025 | 268,836,125 | 25·397 | 8·640 |
| 646 | 2029·47 | 327759·22 | 417,316 | 269,586,136 | 25·416 | 8·644 |
| 647 | 2032·61 | 328774·74 | 418,609 | 270,840,023 | 25·436 | 8·649 |
| 648 | 2035·75 | 329791·83 | 419,904 | 272,097,792 | 25·456 | 8·653 |
| 649 | 2038·89 | 330810·49 | 421,201 | 273,359,449 | 25·475 | 8·658 |
| 650 | 2042·04 | 331830·72 | 422,500 | 274,625,000 | 25·495 | 8·662 |
| 651 | 2045·18 | 332852·53 | 423,801 | 275,894,451 | 25·515 | 8·667 |
| 652 | 2048·32 | 333875·90 | 425,104 | 277,167,808 | 25·534 | 8·671 |
| 653 | 2051·46 | 334900·85 | 426,409 | 278,445,077 | 25·554 | 8·676 |
| 654 | 2054·60 | 335927·36 | 427,716 | 279,726,264 | 25·573 | 8·680 |
| 655 | 2057·74 | 336955·45 | 429,025 | 281,011,375 | 25·593 | 8·684 |
| 656 | 2060·88 | 337985·10 | 430,336 | 282,800,416 | 25·612 | 8·689 |
| 657 | 2064·03 | 339016·33 | 431,649 | 283,593,393 | 25·632 | 8·693 |
| 658 | 2067·17 | 340049·13 | 432,964 | 284,890,312 | 25·651 | 8·698 |
| 659 | 2070·31 | 341083·50 | 434,281 | 286,191,179 | 25·671 | 8·702 |
| 660 | 2073·45 | 342119·44 | 435,600 | 287,496,000 | 25·690 | 8·706 |
| 661 | 2076·59 | 343156·95 | 436,921 | 288,804,781 | 25·710 | 8·711 |
| 662 | 2079·73 | 344196·03 | 438,244 | 290,117,528 | 25·720 | 8·715 |
| 663 | 2082·88 | 345236·69 | 439,569 | 291,434,247 | 25·749 | 8·719 |
| 664 | 2086·02 | 346278·91 | 440,896 | 292,754,944 | 25·768 | 8·724 |
| 665 | 2089·16 | 347322·70 | 442,225 | 294,079,625 | 25·787 | 8·728 |
| 666 | 2092·30 | 348368·07 | 443,556 | 295,408,296 | 25·807 | 8·733 |
| 667 | 2095·44 | 349415·00 | 444,889 | 296,740,963 | 25·826 | 8·737 |
| 668 | 2098·58 | 350463·51 | 446,224 | 298,077,632 | 25·846 | 8·742 |
| 669 | 2101·73 | 351513·59 | 447,561 | 299,418,309 | 25·865 | 8·746 |

| No. or Diam. | Circumference. | Circular Area. | Square. | Cube. | Square Root. | Cube Root. |
|---|---|---|---|---|---|---|
| **670** | 2104·87 | 352565·24 | 448,900 | 300,763,000 | 25·884 | 8·750 |
| **671** | 2108·01 | 353618·43 | 450,241 | 302,111,711 | 25·904 | 8·753 |
| **672** | 2111·15 | 354673·24 | 451,584 | 303,464,448 | 25·923 | 8·759 |
| **673** | 2114·29 | 355729·60 | 452,929 | 304,821,217 | 25·942 | 8·763 |
| **674** | 2117·43 | 356787·54 | 454,276 | 306,182,024 | 25·961 | 8·768 |
| **675** | 2120·58 | 357847·04 | 455,625 | 307,546,875 | 25·981 | 8·772 |
| **676** | 2123·72 | 358908·11 | 456,976 | 308,915,776 | 26·000 | 8·776 |
| **677** | 2126·86 | 359970·75 | 458,329 | 310,288,733 | 26·019 | 8·781 |
| **678** | 2130·00 | 361034·97 | 459,684 | 311,665,752 | 26·038 | 8·785 |
| **679** | 2133·14 | 362100·75 | 461,041 | 313,046,839 | 26·058 | 8·789 |
| **680** | 2136·28 | 363168·11 | 462,400 | 314,432,000 | 26·077 | 8·794 |
| **681** | 2139·42 | 364237·04 | 463,761 | 315,821,241 | 26·096 | 8·798 |
| **682** | 2142·57 | 365307·54 | 465,124 | 317,214,568 | 26·115 | 8·802 |
| **683** | 2145·71 | 366379·60 | 466,489 | 318,611,987 | 26·134 | 8·807 |
| **684** | 2148·85 | 367453·24 | 467,856 | 320,013,504 | 26·153 | 8·811 |
| **685** | 2151·99 | 368528·45 | 469,225 | 321,419,125 | 26·172 | 8·815 |
| **686** | 2155·13 | 369605·23 | 470,596 | 322,828,856 | 26·192 | 8·819 |
| **687** | 2158·27 | 370683·59 | 471,969 | 324,242,703 | 26·211 | 8·824 |
| **688** | 2161·42 | 371763·51 | 473,344 | 325,660,672 | 26·229 | 8·828 |
| **689** | 2164·56 | 372845·00 | 474,721 | 327,082,769 | 26·249 | 8·832 |
| **690** | 2167·70 | 373928·07 | 476,100 | 328,509,000 | 26·268 | 8·836 |
| **691** | 2170·84 | 375012·70 | 477,481 | 329,939,371 | 26·287 | 8·841 |
| **692** | 2173·98 | 376098·91 | 478,864 | 331,373,888 | 26·306 | 8·845 |
| **693** | 2177·12 | 377186·68 | 480,249 | 332,812,557 | 26·325 | 8·849 |
| **694** | 2180·27 | 378276·03 | 481,636 | 334,255,384 | 26·344 | 8·853 |
| **695** | 2183·41 | 379366·95 | 483,025 | 335,702,375 | 26·363 | 8·858 |
| **696** | 2186·55 | 380459·44 | 484,416 | 337,153,536 | 26·382 | 8·862 |
| **697** | 2189·69 | 381553·50 | 485,809 | 338,608,873 | 26·401 | 8·866 |
| **698** | 2192·83 | 382649·43 | 487,204 | 340,068,392 | 26·419 | 8·870 |
| **699** | 2195·97 | 383746·33 | 488,601 | 341,532,099 | 26·439 | 8·875 |
| **700** | 2199·12 | 384845·10 | 490,000 | 343,000,000 | 26·457 | 8·879 |
| **701** | 2202·26 | 385945·44 | 491,401 | 344,472,101 | 26·476 | 8·883 |
| **702** | 2205·40 | 387047·36 | 492,804 | 345,948,088 | 26·495 | 8·887 |
| **703** | 2208·54 | 388150·84 | 494,209 | 347,428,927 | 26·514 | 8·892 |
| **704** | 2211·68 | 389255·90 | 495,616 | 348,913,664 | 26·533 | 8·896 |
| **705** | 2214·82 | 390362·52 | 497,025 | 350,402,625 | 26·552 | 8·900 |
| **706** | 2217·96 | 391470·32 | 498,436 | 351,895,816 | 26·571 | 8·904 |
| **707** | 2221·11 | 392580·49 | 499,849 | 353,393,243 | 26·589 | 8·908 |
| **708** | 2224·25 | 393691·83 | 501,264 | 354,894,912 | 26·608 | 8·913 |
| **709** | 2227·39 | 394804·74 | 502,681 | 356,400,829 | 26·627 | 8·917 |
| **710** | 2230·53 | 395919·21 | 504,100 | 357,911,000 | 26·644 | 8·921 |
| **711** | 2233·67 | 397035·27 | 505,521 | 359,425,431 | 26·664 | 8·925 |

| No. or Diam. | Circumference. | Circular Area. | Square. | Cube. | Square Root. | Cube Root. |
|---|---|---|---|---|---|---|
| **712** | 2236·81 | 398152·89 | 506,944 | 360,944,128 | 26·683 | 8·929 |
| **713** | 2239·96 | 399272·08 | 508,369 | 362,467,097 | 26·702 | 8·934 |
| **714** | 2243·10 | 400392·84 | 509,796 | 363,994,344 | 26·721 | 8·938 |
| **715** | 2246·24 | 401515·18 | 511,225 | 365,525,875 | 26·739 | 8·942 |
| **716** | 2249·38 | 402639·08 | 512,656 | 367,061,696 | 26·758 | 8·946 |
| **717** | 2252·52 | 403764·56 | 514,089 | 368,601,813 | 26·777 | 8·950 |
| **718** | 2255·66 | 404891·60 | 515,524 | 370,146,232 | 26·795 | 8·954 |
| **719** | 2258·81 | 406020·22 | 516,961 | 371,694,959 | 26·814 | 8·959 |
| **720** | 2261·95 | 407150·41 | 518,400 | 373,248,000 | 26·833 | 8·963 |
| **721** | 2265·09 | 408282·17 | 519,841 | 374,805,361 | 26·851 | 8·967 |
| **722** | 2268·23 | 409415·50 | 521,284 | 376,367,048 | 26·870 | 8·971 |
| **723** | 2271·37 | 410550·40 | 522,729 | 377,933,067 | 26·889 | 8·975 |
| **724** | 2274·51 | 411686·87 | 524,176 | 379,503,424 | 26·907 | 8·979 |
| **725** | 2277·66 | 412824·91 | 525,625 | 381,078,125 | 26·926 | 8·983 |
| **726** | 2280·80 | 413964·52 | 527,076 | 382,657,176 | 26·944 | 8·988 |
| **727** | 2283·94 | 415105·71 | 528,529 | 384,240,583 | 26·963 | 8·992 |
| **728** | 2287·08 | 416248·46 | 529,984 | 385,828,352 | 26·991 | 8·996 |
| **729** | 2290·22 | 417392·79 | 531,441 | 387,420,489 | 27·000 | 9·000 |
| **730** | 2293·36 | 418538·68 | 532,900 | 389,017,000 | 27·018 | 9·004 |
| **731** | 2296·50 | 419686·15 | 534,361 | 390,617,891 | 27·037 | 9·008 |
| **732** | 2299·65 | 420835·19 | 535,824 | 392,223,168 | 27·055 | 9·012 |
| **733** | 2302·79 | 421985·79 | 537,289 | 393,832,837 | 27·074 | 9·016 |
| **734** | 2305·93 | 423137·97 | 538,756 | 395,446,904 | 27·092 | 9·020 |
| **735** | 2309·07 | 424291·72 | 540,225 | 397,065,375 | 27·111 | 9·023 |
| **736** | 2312·21 | 425447·04 | 541,696 | 398,688,256 | 27·129 | 9·029 |
| **737** | 2315·35 | 426603·93 | 543,169 | 400,315,553 | 27·148 | 9·033 |
| **738** | 2318·50 | 427762·40 | 544,644 | 401,947,272 | 27·166 | 9·037 |
| **739** | 2321·64 | 428922·43 | 546,121 | 403,583,419 | 27·184 | 9·041 |
| **740** | 2324·78 | 430084·03 | 547,600 | 405,224,000 | 27·203 | 9·045 |
| **741** | 2327·92 | 431247·21 | 549,081 | 406,869,021 | 27·221 | 9·049 |
| **742** | 2331·06 | 432411·95 | 550,564 | 408,518,488 | 27·239 | 9·053 |
| **743** | 2334·20 | 433578·27 | 552,049 | 410,172,407 | 27·258 | 9·057 |
| **744** | 2337·35 | 434746·16 | 553,536 | 411,830,784 | 27·276 | 9·061 |
| **745** | 2340·49 | 435915·62 | 555,025 | 413,493,625 | 27·295 | 9·065 |
| **746** | 2343·63 | 437086·64 | 556,516 | 415,160,936 | 27·313 | 9·069 |
| **747** | 2346·77 | 438259·24 | 558,009 | 416,832,723 | 27·331 | 9·073 |
| **748** | 2349·91 | 439433·41 | 559,504 | 418,508,992 | 27·349 | 9·077 |
| **749** | 2353·05 | 440609·16 | 561,001 | 420,189,749 | 27·368 | 9·081 |
| **750** | 2356·20 | 441786·47 | 562,500 | 421,875,000 | 27·386 | 9·086 |
| **751** | 2359·34 | 442965·35 | 564,001 | 423,564,751 | 27·404 | 9·089 |
| **752** | 2362·48 | 444145·80 | 565,504 | 424,525,900 | 27·423 | 9·094 |
| **753** | 2365·62 | 445327·83 | 567,009 | 426,957,777 | 27·441 | 9·098 |

| No. or Diam. | Circumference. | Circular Area. | Square. | Cube. | Square Root. | Cube Root. |
|---|---|---|---|---|---|---|
| 754 | 2368·76 | 446511·42 | 568,516 | 428,661,064 | 27·459 | 9·102 |
| 755 | 2371·90 | 447696·59 | 570,025 | 430,368,875 | 27·477 | 9·106 |
| 756 | 2375·04 | 448883·32 | 571,536 | 432,081,216 | 27·495 | 9·109 |
| 757 | 2378·19 | 450071·63 | 573,049 | 433,798,093 | 27·514 | 9·114 |
| 758 | 2381·33 | 451261·51 | 574,564 | 435,519,512 | 27·532 | 9·118 |
| 759 | 2384·47 | 452452·96 | 576,081 | 437,245,479 | 27·549 | 8·122 |
| 760 | 2387·61 | 453645·98 | 577,600 | 438,976,000 | 27·568 | 9·126 |
| 761 | 2390·75 | 454840·57 | 579,121 | 440,711,081 | 27·586 | 9·129 |
| 762 | 2393·89 | 456036·73 | 580,644 | 442,450,728 | 27·604 | 9·134 |
| 763 | 2397·04 | 457234·46 | 582,169 | 444,194,947 | 27·622 | 9·138 |
| 764 | 2400·18 | 458433·77 | 583,696 | 445,943,744 | 27·640 | 9·142 |
| 765 | 2403·32 | 459634·64 | 585,225 | 447,697,125 | 27·659 | 9·146 |
| 766 | 2406·46 | 460837·08 | 586,756 | 449,455,096 | 27·677 | 9·149 |
| 767 | 2409·60 | 462041·10 | 588,289 | 451,217,663 | 27·695 | 9·154 |
| 768 | 2412·74 | 463246·69 | 589,824 | 452,984,832 | 27·713 | 9·158 |
| 769 | 2415·89 | 464453·84 | 591,361 | 454,756,609 | 27·731 | 9·162 |
| 770 | 2419·03 | 465662·57 | 592,900 | 456,533,000 | 27·749 | 9·166 |
| 771 | 2422·17 | 466872·87 | 594,441 | 458,314,011 | 27·767 | 9·169 |
| 772 | 2425·31 | 468084·74 | 595,984 | 460,099,648 | 27·785 | 9·173 |
| 773 | 2428·45 | 469298·18 | 597,529 | 461,889,917 | 27·803 | 9·177 |
| 774 | 2431·59 | 470513·19 | 599,076 | 463,684,824 | 27·821 | 9·181 |
| 775 | 2434·73 | 471729·77 | 600,625 | 465,484,375 | 27·839 | 9·185 |
| 776 | 2437·88 | 472947·92 | 602,176 | 467,288,576 | 27·857 | 9·189 |
| 777 | 2441·02 | 474167·65 | 603,729 | 469,097,433 | 27·875 | 9·193 |
| 778 | 2444·16 | 475388·94 | 605,284 | 470,910,952 | 27·893 | 9·197 |
| 779 | 2447·30 | 476611·81 | 606,841 | 472,729,139 | 27·910 | 9·201 |
| 780 | 2450·44 | 477836·24 | 608,400 | 474,552,000 | 27·928 | 9·205 |
| 781 | 2453·58 | 479062·25 | 609,961 | 476,379,541 | 27·946 | 9·209 |
| 782 | 2456·73 | 480289·83 | 611,524 | 478,211,768 | 27·964 | 9·213 |
| 783 | 2459·87 | 481518·97 | 613,089 | 480,048,687 | 27·982 | 9·217 |
| 784 | 2463·01 | 482749·69 | 614,656 | 481,890,304 | 28·000 | 9·221 |
| 785 | 2466·15 | 483981·98 | 616,225 | 483,736,025 | 28·017 | 9·225 |
| 786 | 2469·29 | 485215·84 | 617,796 | 485,587,656 | 28·036 | 9·229 |
| 787 | 2472·43 | 486451·28 | 619,369 | 487,443,403 | 28·053 | 9·233 |
| 788 | 2475·58 | 487688·28 | 620,944 | 489,303,872 | 28·071 | 9·237 |
| 789 | 2478·72 | 488926·85 | 622,521 | 491,169,069 | 28·089 | 9·240 |
| 790 | 2481·86 | 490166·99 | 624,100 | 493,039,000 | 28·107 | 9·244 |
| 791 | 2485·00 | 491408·71 | 625,681 | 494,913,671 | 28·125 | 9·248 |
| 792 | 2488·14 | 492651·99 | 627,264 | 496,793,088 | 28·142 | 9·252 |
| 793 | 2491·28 | 493896·85 | 628,849 | 498,677,257 | 28·160 | 9·256 |
| 794 | 2494·43 | 495143·28 | 630,436 | 500,566,184 | 28·178 | 9·260 |
| 795 | 2497·57 | 496391·27 | 632,025 | 502,459,875 | 28·196 | 9·264 |

| No. or Diam | Circumference. | Circular Area. | Square. | Cube. | Square Root. | Cube Root. |
|---|---|---|---|---|---|---|
| **796** | 2500·71 | 497640·84 | 633,616 | 504,358,336 | 28·213 | 9·268 |
| **797** | 2503·85 | 498891·98 | 635,209 | 506,261,573 | 28·231 | 9·271 |
| **798** | 2506·99 | 500144·69 | 636,804 | 508,169,592 | 28·249 | 9·275 |
| **799** | 2510·13 | 501398·97 | 638,401 | 510,082,399 | 28·266 | 9·279 |
| **800** | 2513·27 | 502654·82 | 640,000 | 512,000,000 | 28·284 | 9·283 |
| **801** | 2516·42 | 503912·25 | 641,601 | 513,922,401 | 28·302 | 9·287 |
| **802** | 2519·56 | 505171·24 | 643,204 | 515,849,608 | 28·319 | 9·291 |
| **803** | 2522·70 | 506431·80 | 644,809 | 517,781,627 | 28·337 | 9·295 |
| **804** | 2525·84 | 507693·94 | 646,416 | 519,718,464 | 28·355 | 9·299 |
| **805** | 2528·98 | 508957·65 | 648,025 | 521,660,125 | 28·372 | 9·302 |
| **806** | 2532·12 | 510222·92 | 649,636 | 523,606,616 | 28·390 | 9·306 |
| **807** | 2535·27 | 511489·77 | 651,249 | 525,557,943 | 28·408 | 9·310 |
| **808** | 2538·41 | 512758·19 | 652,864 | 527,514,112 | 28·425 | 9·314 |
| **809** | 2541·55 | 514028·19 | 654,481 | 529,474,129 | 28·443 | 9·318 |
| **810** | 2544·69 | 515299·74 | 656,100 | 531,441,000 | 28·460 | 9·321 |
| **811** | 2547·83 | 516572·86 | 657,721 | 533,411,731 | 28·478 | 9·325 |
| **812** | 2550·97 | 517847·57 | 659,344 | 535,387,328 | 28·496 | 9·329 |
| **813** | 2554·12 | 519123·84 | 660,969 | 537,366,797 | 28·513 | 9·333 |
| **814** | 2557·26 | 520401·68 | 662,596 | 539,353,144 | 28·531 | 9·337 |
| **815** | 2560·40 | 521681·10 | 664,225 | 541,343,375 | 28·548 | 9·341 |
| **816** | 2563·54 | 522962·08 | 665,856 | 543,338,496 | 28·566 | 9·345 |
| **817** | 2566·68 | 524244·63 | 667,489 | 545,338,513 | 28·583 | 9·348 |
| **818** | 2569·82 | 525528·76 | 669,124 | 547,343,432 | 28·601 | 9·352 |
| **819** | 2572·96 | 526814·46 | 670,761 | 549,353,259 | 28·618 | 9·356 |
| **820** | 2576·11 | 528101·73 | 672,400 | 551,368,000 | 28·636 | 9·360 |
| **821** | 2579·25 | 529390·56 | 674,041 | 553,387,661 | 28·653 | 9·364 |
| **822** | 2582·39 | 530680·97 | 675,684 | 555,412,248 | 28·670 | 9·367 |
| **823** | 2585·53 | 531972·95 | 677,329 | 557,441,767 | 28·688 | 9·371 |
| **824** | 2588·67 | 533266·50 | 678,976 | 559,476,224 | 28·705 | 9·375 |
| **825** | 2591·81 | 534561·63 | 680,625 | 561,515,625 | 28·723 | 9·379 |
| **826** | 2594·96 | 535858·32 | 682,276 | 563,559,976 | 28·740 | 9·383 |
| **827** | 2598·10 | 537156·58 | 683,929 | 565,609,283 | 28·758 | 9·386 |
| **828** | 2601·24 | 538456·41 | 685,584 | 567,663,552 | 28·775 | 9·390 |
| **829** | 2604·38 | 539757·82 | 687,241 | 569,722,789 | 28·792 | 9·394 |
| **830** | 2607·52 | 541060·79 | 688,900 | 571,787,000 | 28·810 | 9·398 |
| **831** | 2610·66 | 542365·34 | 690,561 | 573,856,191 | 28·827 | 9·401 |
| **832** | 2613·81 | 543671·46 | 692,224 | 575,930,368 | 28·844 | 9·405 |
| **833** | 2616·95 | 544979·15 | 693,889 | 578,009,537 | 28·862 | 9·409 |
| **834** | 2620·09 | 546288·40 | 695,556 | 580,093,704 | 28·879 | 9·413 |
| **835** | 2623·23 | 547599·23 | 697,225 | 582,182,875 | 28·896 | 9·417 |
| **836** | 2626·37 | 548911·63 | 698,896 | 584,277,056 | 28·914 | 9·420 |
| **837** | 2629·51 | 550225·61 | 700,569 | 586,376,253 | 28·931 | 9·424 |

| No. or Diam. | Circumference. | Circular Area. | Square. | Cube. | Square Root. | Cube Root. |
|---|---|---|---|---|---|---|
| **838** | 2632·64 | 551541·15 | 702,244 | 588,480,472 | 28·948 | 9·428 |
| **839** | 2635·80 | 552858·26 | 703,921 | 590,589,719 | 28·965 | 9·432 |
| **840** | 2638·94 | 554176·94 | 705,600 | 592,704,000 | 28·983 | 9·435 |
| **841** | 2642·08 | 555497·20 | 707,281 | 594,823,321 | 29·000 | 9·439 |
| **842** | 2645·22 | 556819·02 | 708,964 | 596,947,688 | 29·017 | 9·443 |
| **843** | 2648·36 | 558142·42 | 710,649 | 599,077,107 | 29·034 | 9·447 |
| **844** | 2651·50 | 559467·39 | 712,336 | 601,211,584 | 29·052 | 9·450 |
| **845** | 2654·65 | 560793·92 | 714,025 | 603,351,125 | 29·069 | 9·454 |
| **846** | 2657·79 | 562122·03 | 715,716 | 605,495,736 | 29·086 | 9·458 |
| **847** | 2660·93 | 563451·71 | 717,409 | 607,645,423 | 29·103 | 9·461 |
| **848** | 2664·07 | 564782·96 | 719,104 | 609,800,192 | 29·120 | 9·465 |
| **849** | 2667·21 | 566115·78 | 720,801 | 611,960,049 | 29·138 | 9·469 |
| **850** | 2670·35 | 567450·17 | 722,500 | 614,125,000 | 29·155 | 9·473 |
| **851** | 2673·50 | 568786·14 | 724,201 | 616,295,051 | 29·172 | 9·476 |
| **852** | 2676·64 | 570123·67 | 725,904 | 618,470,208 | 29·189 | 9·480 |
| **853** | 2679·78 | 571462·77 | 727,609 | 620,650,477 | 29·206 | 9·483 |
| **854** | 2682·92 | 572803·45 | 729,316 | 622,835,864 | 29·223 | 9·487 |
| **855** | 2686·06 | 574145·69 | 731,025 | 625,026,375 | 29·240 | 9·491 |
| **856** | 2689·20 | 575489·51 | 732,736 | 627,222,016 | 29·257 | 9·495 |
| **857** | 2692·35 | 576834·90 | 734,449 | 629,422,793 | 29·274 | 9·499 |
| **858** | 2695·49 | 578181·85 | 736,164 | 631,628,712 | 29·292 | 9·502 |
| **859** | 2698·63 | 579530·38 | 737,881 | 633,839,779 | 29·309 | 9·506 |
| **860** | 2701·77 | 580880·48 | 739,600 | 636,056,000 | 29·326 | 9·509 |
| **861** | 2704·91 | 582232·15 | 741,321 | 638,277,381 | 29·343 | 9·513 |
| **862** | 2708·05 | 583585·39 | 743,044 | 640,503,928 | 29·360 | 9·517 |
| **863** | 2711·19 | 584940·21 | 744,769 | 642,735,647 | 29·377 | 9·520 |
| **864** | 2714·34 | 586296·59 | 746,496 | 644,972,544 | 29·394 | 9·524 |
| **865** | 2717·45 | 587654·54 | 748,225 | 647,214,625 | 29·411 | 9·528 |
| **866** | 2720·62 | 589014·07 | 749,956 | 649,461,896 | 29·428 | 9·532 |
| **867** | 2723·76 | 590375·16 | 751,689 | 651,714,363 | 29·445 | 9·535 |
| **868** | 2726·90 | 591737·83 | 753,424 | 653,972,032 | 29·462 | 9·539 |
| **869** | 2730·04 | 593102·06 | 755,161 | 656,234,909 | 29·479 | 9·543 |
| **870** | 2733·19 | 594467·87 | 756,900 | 658,503,000 | 29·496 | 9·546 |
| **871** | 2736·33 | 595835·25 | 758,641 | 660,776,311 | 29·513 | 9·550 |
| **872** | 2739·47 | 597204·20 | 760,384 | 663,054,848 | 29·529 | 9·554 |
| **873** | 2742·61 | 598574·72 | 762,129 | 665,338,617 | 29·546 | 9·557 |
| **874** | 2745·75 | 599946·81 | 763,876 | 667,627,624 | 29·563 | 9·561 |
| **875** | 2748·89 | 601320·47 | 765,625 | 669,921,875 | 29·580 | 9·565 |
| **876** | 2752·04 | 602695·70 | 767,376 | 672,221,376 | 29·597 | 9·568 |
| **877** | 2755·18 | 604072·50 | 769,129 | 674,526,133 | 29·614 | 9·572 |
| **878** | 2758·32 | 605450·88 | 770,884 | 676,836,152 | 29·631 | 9·575 |
| **879** | 2761·46 | 606830·82 | 772,641 | 679,151,439 | 29·648 | 9·579 |

| No. or Diam. | Circumference. | Circular Area. | Square. | Cube. | Square Root. | Cube Root. |
|---|---|---|---|---|---|---|
| **880** | 2764·60 | 608212·34 | 774,400 | 681,472,000 | 29·665 | 9·583 |
| **881** | 2767·74 | 609595·42 | 776,161 | 683,797,841 | 29·682 | 9·586 |
| **882** | 2770·89 | 610980·08 | 777,924 | 686,128,968 | 29·698 | 9·590 |
| **883** | 2774·03 | 612366·31 | 779,689 | 688,465,387 | 29·715 | 9·594 |
| **884** | 2777·17 | 613754·11 | 781,456 | 690,807,104 | 29·732 | 9·597 |
| **885** | 2780·31 | 615143·48 | 783,225 | 693,154,125 | 29·749 | 9·601 |
| **886** | 2783·45 | 616534·42 | 784,996 | 695,506,456 | 29·766 | 9·604 |
| **887** | 2786·59 | 617926·93 | 786,769 | 697,864,103 | 29·782 | 9·608 |
| **888** | 2789·73 | 619321·01 | 788,544 | 700,227,072 | 29·799 | 9·612 |
| **889** | 2792·88 | 620716·66 | 790,321 | 702,595,369 | 29·816 | 9·615 |
| **890** | 2796·02 | 622113·89 | 792,100 | 704,969,000 | 29·833 | 9·619 |
| **891** | 2799·16 | 623512·68 | 793,881 | 707,347,971 | 29·850 | 9·623 |
| **892** | 2802·30 | 624913·04 | 795,664 | 709,732,288 | 29·866 | 9·626 |
| **893** | 2805·44 | 626314·98 | 797,449 | 712,121,957 | 29·883 | 9·630 |
| **894** | 2808·58 | 627718·49 | 799,236 | 714,516,984 | 29·900 | 9·633 |
| **895** | 2811·73 | 629128·56 | 801,025 | 716,917,375 | 29·916 | 9·637 |
| **896** | 2814·87 | 630530·21 | 802,816 | 719,323,136 | 29·933 | 9·640 |
| **897** | 2818·01 | 631938·43 | 804,609 | 721,734,273 | 29·950 | 9·644 |
| **898** | 2821·15 | 633348·22 | 806,404 | 724,150,792 | 29·967 | 9·648 |
| **899** | 2824·29 | 634759·58 | 808,201 | 726,572,699 | 29·983 | 9·651 |
| **900** | 2827·43 | 636172·51 | 810,000 | 729,000,000 | 30·000 | 9·655 |
| **901** | 2830·58 | 637587·01 | 811,804 | 731,432,701 | 30·017 | 9·658 |
| **902** | 2833·72 | 639003·09 | 813,604 | 733,870,808 | 30·033 | 9·662 |
| **903** | 2836·86 | 640420·73 | 815,409 | 736,314,327 | 30·050 | 9·666 |
| **904** | 2840·00 | 641839·95 | 817,216 | 738,763,264 | 30·066 | 9·669 |
| **905** | 2843·14 | 643260·73 | 819,025 | 741,217,625 | 30·083 | 9·673 |
| **906** | 2846·28 | 644683·09 | 820,836 | 743,677,416 | 30·100 | 9·676 |
| **907** | 2849·43 | 646107·01 | 822,649 | 746,142,643 | 30·116 | 9·680 |
| **908** | 2852·57 | 647532·51 | 824,464 | 748,613,312 | 30·133 | 9·683 |
| **909** | 2855·71 | 648959·58 | 826,281 | 751,089,429 | 30·150 | 9·687 |
| **910** | 2858·85 | 650388·21 | 828,100 | 753,571,000 | 30·163 | 9·690 |
| **911** | 2861·99 | 651818·43 | 829,921 | 756,058,031 | 30·183 | 9·694 |
| **912** | 2865·13 | 653250·21 | 831,744 | 758,550,528 | 30·199 | 9·698 |
| **913** | 2868·27 | 654683·56 | 833,569 | 761,048,497 | 30·216 | 9·701 |
| **914** | 2871·42 | 656118·48 | 835,396 | 763,551,944 | 30·232 | 9·705 |
| **215** | 2874·56 | 657554·98 | 837,225 | 766,060,875 | 30·249 | 9·708 |
| **916** | 2877·70 | 658993·04 | 839,056 | 768,575,296 | 30·265 | 9·712 |
| **917** | 2880·84 | 660432·68 | 840,889 | 771,095,213 | 30·282 | 9·715 |
| **918** | 2883·98 | 661873·88 | 842,724 | 773,620,632 | 30·298 | 9·718 |
| **919** | 2887·12 | 663316·66 | 844,561 | 776,151,559 | 30·315 | 9·722 |
| **920** | 2890·27 | 664761·01 | 846,400 | 778,688,000 | 30·331 | 9·726 |
| **921** | 2893·41 | 666206·92 | 848,241 | 781,229,961 | 30·348 | 9·729 |

| No. or Diam. | Circumference. | Circular Area. | Square. | Cube. | Square Root. | Cube Root. |
|---|---|---|---|---|---|---|
| 922 | 2896·55 | 667654·41 | 850,084 | 783,777,448 | 30·364 | 9·733 |
| 923 | 2899·69 | 669103·47 | 851,929 | 786,330,467 | 30·381 | 9·736 |
| 924 | 2902·83 | 670551·10 | 853,776 | 788,889,024 | 30·397 | 9·740 |
| 925 | 2905·97 | 672006·30 | 855,625 | 791,453,125 | 30·414 | 9·743 |
| 926 | 2909·12 | 673460·08 | 857,476 | 794,022,776 | 30·430 | 9·747 |
| 927 | 2912·26 | 674915·42 | 859,329 | 796,597,983 | 30·447 | 9·750 |
| 928 | 2915·40 | 676372·33 | 861,184 | 799,178,752 | 30·463 | 9·754 |
| 929 | 2918·54 | 677830·82 | 863,041 | 801,765,089 | 30·479 | 9·757 |
| 930 | 2921·68 | 679290·87 | 864,900 | 804,357,000 | 30·496 | 9·761 |
| 931 | 2924·82 | 680752·50 | 866,761 | 806,954,491 | 30·512 | 9·764 |
| 932 | 2927·96 | 682215·69 | 868,624 | 809,557,568 | 30·529 | 9·768 |
| 933 | 2931·11 | 683680·46 | 870,489 | 812,166,237 | 30·545 | 9·771 |
| 934 | 2934·25 | 685146·80 | 872,356 | 814,780,504 | 30·561 | 9·775 |
| 935 | 2937·39 | 686614·71 | 874,225 | 817,400,375 | 30·578 | 9·778 |
| 936 | 2940·53 | 688084·19 | 876,096 | 820,025,856 | 30·594 | 9·783 |
| 937 | 2943·67 | 689555·24 | 877,969 | 822,656,953 | 30·610 | 9·785 |
| 938 | 2946·81 | 691027·86 | 879,844 | 825,293,672 | 30·627 | 9·789 |
| 939 | 2949·96 | 692502·05 | 881,721 | 827,936,019 | 30·643 | 9·792 |
| 940 | 2953·10 | 693977·82 | 883,600 | 830,584,000 | 30·659 | 9·796 |
| 941 | 2956·24 | 695455·15 | 885,481 | 833,237,621 | 30·676 | 9·799 |
| 942 | 2959·38 | 696934·06 | 887,364 | 835,896,888 | 30·692 | 9·803 |
| 943 | 2962·52 | 698414·53 | 889,249 | 838,561,807 | 30·708 | 9·806 |
| 944 | 2965·66 | 699896·58 | 891,136 | 841,232,384 | 30·724 | 9·810 |
| 945 | 2968·81 | 701380·28 | 893,025 | 843,908,625 | 30·741 | 9·813 |
| 946 | 2971·95 | 702865·38 | 894,916 | 846,590,536 | 30·757 | 9·817 |
| 947 | 2975·09 | 704352·14 | 896,809 | 849,278,123 | 30·773 | 9·820 |
| 948 | 2978·23 | 705840·47 | 898,704 | 851,971,392 | 30·790 | 9·823 |
| 949 | 2981·37 | 707330·37 | 900,601 | 854,670,349 | 30·806 | 9·827 |
| 950 | 2984·51 | 708821·84 | 902,500 | 857,375,000 | 30·822 | 9·830 |
| 951 | 2987·66 | 710314·88 | 904,401 | 860,085,351 | 30·838 | 9·834 |
| 952 | 2990·80 | 711809·58 | 906,304 | 862,801,408 | 30·854 | 9·837 |
| 953 | 2993·94 | 713305·68 | 908,209 | 865,523,177 | 30·871 | 9·841 |
| 954 | 2997·08 | 714803·48 | 910,116 | 868,250,664 | 30·887 | 9·844 |
| 955 | 3000·22 | 716302·76 | 912,025 | 870,983,875 | 30·903 | 9·848 |
| 956 | 3003·36 | 717803·66 | 913,936 | 873,722,816 | 30·919 | 9·851 |
| 957 | 3006·50 | 719306·12 | 915,849 | 876,467,493 | 30·935 | 9·854 |
| 958 | 3009·65 | 720810·16 | 917,764 | 879,217,912 | 30·951 | 9·858 |
| 959 | 3012·79 | 722315·77 | 919,681 | 881,974,079 | 30·968 | 9·861 |
| 960 | 3015·93 | 723822·95 | 921,600 | 884,736,000 | 30·984 | 9·865 |
| 961 | 3019·07 | 725331·70 | 923,521 | 887,503,681 | 31·000 | 9·868 |
| 962 | 3022·21 | 726842·02 | 925,444 | 890,277,128 | 31·016 | 9·872 |
| 963 | 3025·35 | 728353·91 | 927,369 | 893,056,347 | 31·032 | 9·875 |

| No. or Diam. | Circumference. | Circular Area. | Square. | Cube. | Square Root. | Cube Root. |
|---|---|---|---|---|---|---|
| 964 | 3028·50 | 729867·37 | 929,296 | 895,841,344 | 31·048 | 9·878 |
| 965 | 3031·64 | 731382·40 | 931,225 | 898,632,125 | 31·064 | 9·881 |
| 966 | 3034·78 | 732899·01 | 933,156 | 901,428,696 | 31·080 | 9·885 |
| 967 | 3037·92 | 734417·18 | 935,089 | 904,231,063 | 31·097 | 9·889 |
| 968 | 3041·06 | 735936·93 | 937,024 | 907,039,232 | 31·113 | 9·892 |
| 969 | 3044·20 | 737458·25 | 938,961 | 909,853,209 | 31·129 | 9·895 |
| 970 | 3047·35 | 738981·13 | 940,900 | 912,673,000 | 31·145 | 9·899 |
| 971 | 3050·49 | 740505·59 | 942,841 | 915,498,611 | 31·161 | 9·902 |
| 972 | 3053·63 | 742031·62 | 944,784 | 918,330,048 | 31·177 | 9·905 |
| 973 | 3056·77 | 743559·22 | 946,729 | 921,167,317 | 31·193 | 9·909 |
| 974 | 3059·91 | 745088·39 | 948,676 | 924,010,424 | 31·209 | 9·912 |
| 975 | 3063·05 | 746619·13 | 950,625 | 926,859,375 | 31·225 | 9·916 |
| 976 | 3066·19 | 748151·44 | 952,576 | 929,714,176 | 31·241 | 9·919 |
| 977 | 3069·34 | 749685·32 | 954,529 | 932,574,833 | 31·257 | 9·923 |
| 978 | 3072·48 | 751220·78 | 956,484 | 935,441,352 | 31·273 | 9·926 |
| 979 | 3075·62 | 752757·80 | 958,441 | 938,313,739 | 31·289 | 9·929 |
| 980 | 3078·76 | 754296·40 | 960,400 | 941,192,000 | 31·305 | 9·933 |
| 981 | 3081·90 | 755836·56 | 962,361 | 914,076,141 | 31·321 | 9·936 |
| 982 | 3085·04 | 757378·30 | 964,324 | 946,966,168 | 31·337 | 9·940 |
| 983 | 3088·19 | 758921·61 | 966,289 | 949,862,087 | 31.353 | 9·943 |
| 984 | 3091·33 | 760466·18 | 968,256 | 952,763,904 | 31·369 | 9·946 |
| 985 | 3094·47 | 762012·93 | 970,225 | 955,671,625 | 31·385 | 9·950 |
| 986 | 3097·61 | 763560·95 | 972,196 | 958,585,256 | 31·401 | 9·953 |
| 987 | 3100·75 | 765110·54 | 974,169 | 961,504,803 | 31·416 | 9·956 |
| 988 | 3103·89 | 766661·71 | 976,144 | 964,430,272 | 31·432 | 9·960 |
| 989 | 3107·04 | 768214·44 | 978,121 | 967,361,669 | 31·448 | 9·963 |
| 990 | 3110·18 | 769768·74 | 980,100 | 970,299,000 | 31·464 | 9·966 |
| 991 | 3113·32 | 771324·61 | 982,081 | 973,242,271 | 31·480 | 9·970 |
| 992 | 3116·46 | 772882·06 | 984,064 | 976,191,488 | 31·496 | 9·973 |
| 993 | 3119·60 | 774441·07 | 986,049 | 979,146,657 | 31·512 | 9·977 |
| 994 | 3122·74 | 776001·66 | 988,036 | 982,107,784 | 31·528 | 9·980 |
| 995 | 3125·89 | 777563·82 | 990,025 | 985,074,875 | 31·544 | 9·983 |
| 996 | 3129·03 | 779127·54 | 992,016 | 988,047,936 | 31·559 | 9·987 |
| 997 | 3132·17 | 780692·84 | 994,009 | 991,026,973 | 31·575 | 9·990 |
| 998 | 3135·31 | 782259·71 | 996,004 | 994,011,992 | 31·591 | 9·993 |
| 999 | 3138·45 | 783828·15 | 998,001 | 997,002,999 | 31·607 | 9·997 |
| 1000 | 3141·60 | 785398·16 | 1,000,000 | 1,000,000,000 | 31·623 | 10·000 |

## TABLE 2.—CIRCLES: DIAMETER (FROM $\frac{1}{16}$ TO 120), CIRCUMFERENCE, AND AREA.*

| Diameter. | Circumference. | Area. | Diameter. | Circumference. | Area. |
|---|---|---|---|---|---|
| $\frac{1}{16}$ | ·1963 | ·00307 | $2\frac{9}{16}$ | 8·0503 | 5·1573 |
| $\frac{1}{8}$ | ·3927 | ·01227 | $2\frac{5}{8}$ | 8·2467 | 5·4119 |
| $\frac{3}{16}$ | ·5890 | ·02761 | $2\frac{11}{16}$ | 8·4430 | 5·6723 |
| $\frac{1}{4}$ | ·7854 | ·04909 | $2\frac{3}{4}$ | 8·6394 | 5·9395 |
| $\frac{5}{16}$ | ·9817 | ·07670 | $2\frac{13}{16}$ | 8·8357 | 6·2126 |
| $\frac{3}{8}$ | 1·1781 | ·1104 | $2\frac{7}{8}$ | 9·0321 | 6·4918 |
| $\frac{7}{16}$ | 1·3744 | ·1503 | $2\frac{15}{16}$ | 9·2284 | 6·7772 |
| $\frac{1}{2}$ | 1·5708 | ·1963 | 3 | 9·4248 | 7·0686 |
| $\frac{9}{16}$ | 1·7771 | ·2485 | $3\frac{1}{16}$ | 9·6211 | 7·3662 |
| $\frac{5}{8}$ | 1·9635 | ·3068 | $3\frac{1}{8}$ | 9·8175 | 7·6699 |
| $\frac{11}{16}$ | 2·1598 | ·3712 | $3\frac{3}{16}$ | 10·014 | 7·9798 |
| $\frac{3}{4}$ | 2·3562 | ·4417 | $3\frac{1}{4}$ | 10·210 | 8·2957 |
| $\frac{13}{16}$ | 2·5525 | ·5185 | $3\frac{5}{16}$ | 10·406 | 8·6180 |
| $\frac{7}{8}$ | 2·7489 | ·6013 | $3\frac{3}{8}$ | 10·602 | 8·9462 |
| $\frac{15}{16}$ | 2·9452 | ·6903 | $3\frac{7}{16}$ | 10·799 | 9·2807 |
| 1 | 3·1416 | ·7854 | $3\frac{1}{2}$ | 10·995 | 9·6211 |
| $1\frac{1}{16}$ | 3·3379 | ·8866 | $3\frac{9}{16}$ | 11·191 | 9·9680 |
| $1\frac{1}{8}$ | 3·5343 | ·9940 | $3\frac{5}{8}$ | 11·388 | 10·320 |
| $1\frac{3}{16}$ | 3·7306 | 1·1075 | $3\frac{11}{16}$ | 11·584 | 10·679 |
| $1\frac{1}{4}$ | 3·9270 | 1·2271 | $3\frac{3}{4}$ | 11·781 | 11·044 |
| $1\frac{5}{16}$ | 4·1233 | 1·3530 | $3\frac{13}{16}$ | 11·977 | 11·416 |
| $1\frac{3}{8}$ | 4·3197 | 1·4848 | $3\frac{7}{8}$ | 12·173 | 11·793 |
| $1\frac{7}{16}$ | 4·5160 | 1·6229 | $3\frac{15}{16}$ | 12·369 | 12·177 |
| $1\frac{1}{2}$ | 4·7124 | 1·7671 | 4 | 12·566 | 12·566 |
| $1\frac{9}{16}$ | 4·9087 | 1·9175 | $4\frac{1}{16}$ | 12·762 | 12·962 |
| $1\frac{5}{8}$ | 5·1051 | 2·0739 | $4\frac{1}{8}$ | 12·959 | 13·364 |
| $1\frac{11}{16}$ | 5·3014 | 2·2365 | $4\frac{3}{16}$ | 13·155 | 13·772 |
| $1\frac{3}{4}$ | 5·4978 | 2·4052 | $4\frac{1}{4}$ | 13·351 | 14·186 |
| $1\frac{13}{16}$ | 5·6941 | 2·5800 | $4\frac{5}{16}$ | 13·547 | 14·606 |
| $1\frac{7}{8}$ | 5·8905 | 2·7611 | $4\frac{3}{8}$ | 13·744 | 15·033 |
| $1\frac{15}{16}$ | 6·0868 | 2·9483 | $4\frac{7}{16}$ | 13·940 | 15·465 |
| 2 | 6·2832 | 3·1416 | $4\frac{1}{2}$ | 14·137 | 15·904 |
| $2\frac{1}{16}$ | 6·4795 | 3·3380 | $4\frac{9}{16}$ | 14·333 | 16·349 |
| $2\frac{1}{8}$ | 6·6759 | 3·5465 | $4\frac{5}{8}$ | 14·529 | 16·800 |
| $2\frac{3}{16}$ | 6·8722 | 3·7584 | $4\frac{11}{16}$ | 14·725 | 17·257 |
| $2\frac{1}{4}$ | 7·0686 | 3·9760 | $4\frac{3}{4}$ | 14·922 | 17·720 |
| $2\frac{5}{16}$ | 7·2649 | 4·2000 | $4\frac{13}{16}$ | 15·119 | 18·190 |
| $2\frac{3}{8}$ | 7·4613 | 4·4302 | $4\frac{7}{8}$ | 15·315 | 18·665 |
| $2\frac{7}{16}$ | 7·6576 | 4·7066 | $4\frac{15}{16}$ | 15·511 | 19·147 |
| $2\frac{1}{2}$ | 7·8540 | 4·9087 | 5 | 15·708 | 19·635 |

* See Introduction, *ante*, p. 2.

| Diameter. | Circumference. | Area. | Diameter. | Circumference. | Area. |
|---|---|---|---|---|---|
| $5\frac{1}{16}$ | 15·904 | 20·129 | $9\frac{3}{8}$ | 29·452 | 69·029 |
| $5\frac{1}{8}$ | 16·100 | 20·629 | $9\frac{1}{2}$ | 29·845 | 70·882 |
| $5\frac{3}{16}$ | 16·296 | 21·135 | $9\frac{5}{8}$ | 30·237 | 72·759 |
| $5\frac{1}{4}$ | 16·493 | 21·647 | $9\frac{3}{4}$ | 30·630 | 74·662 |
| $5\frac{5}{16}$ | 16·689 | 22·166 | $9\frac{7}{8}$ | 31·023 | 76·588 |
| $5\frac{3}{8}$ | 16·886 | 22·690 | 10 | 31·416 | 78·540 |
| $5\frac{7}{16}$ | 17·082 | 23·221 | $10\frac{1}{8}$ | 31·808 | 80·515 |
| $5\frac{1}{2}$ | 17·278 | 23·758 | $10\frac{1}{4}$ | 32·201 | 82·516 |
| $5\frac{9}{16}$ | 17·474 | 24·301 | $10\frac{3}{8}$ | 32·594 | 84·540 |
| $5\frac{5}{8}$ | 17·671 | 24·850 | $10\frac{1}{2}$ | 32·986 | 86·590 |
| $5\frac{11}{16}$ | 17·867 | 25·406 | $10\frac{5}{8}$ | 33·379 | 88·664 |
| $5\frac{3}{4}$ | 18·064 | 25·967 | $10\frac{3}{4}$ | 33·772 | 90·762 |
| $5\frac{13}{16}$ | 18·261 | 26·535 | $10\frac{7}{8}$ | 34·164 | 92·885 |
| $5\frac{7}{8}$ | 18·457 | 27·108 | 11 | 34·558 | 95·033 |
| $5\frac{15}{16}$ | 18·653 | 27·688 | $11\frac{1}{8}$ | 34·950 | 97·205 |
| 6 | 18·849 | 28·274 | $11\frac{1}{4}$ | 35·343 | 99·402 |
| $6\frac{1}{8}$ | 19·242 | 29·464 | $11\frac{3}{8}$ | 35·735 | 101·623 |
| $6\frac{1}{4}$ | 19·635 | 30·679 | $11\frac{1}{2}$ | 36·128 | 103·869 |
| $6\frac{3}{8}$ | 20·027 | 31·919 | $11\frac{5}{8}$ | 36·521 | 106·139 |
| $6\frac{1}{2}$ | 20·420 | 33·183 | $11\frac{3}{4}$ | 36·913 | 108·434 |
| $6\frac{5}{8}$ | 20·813 | 34·471 | $11\frac{7}{8}$ | 37·306 | 110·753 |
| $6\frac{3}{4}$ | 21·205 | 35·784 | 12 | 37·699 | 113·097 |
| $6\frac{7}{8}$ | 21·598 | 37·122 | $12\frac{1}{8}$ | 38·091 | 115·466 |
| 7 | 21·991 | 38·484 | $12\frac{1}{4}$ | 38·484 | 117·859 |
| $7\frac{1}{8}$ | 22·383 | 39·871 | $12\frac{3}{8}$ | 38·877 | 120·276 |
| $7\frac{1}{4}$ | 22·776 | 41·282 | $12\frac{1}{2}$ | 39·270 | 122·718 |
| $7\frac{3}{8}$ | 23·169 | 42·718 | $12\frac{5}{8}$ | 39·662 | 125·184 |
| $7\frac{1}{2}$ | 23·562 | 44·178 | $12\frac{3}{4}$ | 40·055 | 127·676 |
| $7\frac{5}{8}$ | 23·954 | 45·663 | $12\frac{7}{8}$ | 40·448 | 130·192 |
| $7\frac{3}{4}$ | 24·347 | 47·173 | 13 | 40·840 | 132·732 |
| $7\frac{7}{8}$ | 24·740 | 48·707 | $13\frac{1}{8}$ | 41·233 | 135·297 |
| 8 | 25·132 | 50·265 | $13\frac{1}{4}$ | 41·626 | 137·886 |
| $8\frac{1}{8}$ | 25·515 | 51·848 | $13\frac{3}{8}$ | 42·018 | 140·500 |
| $8\frac{1}{4}$ | 25·918 | 53·456 | $13\frac{1}{2}$ | 42·411 | 143·139 |
| $8\frac{3}{8}$ | 26·310 | 55·088 | $13\frac{5}{8}$ | 42·804 | 145·802 |
| $8\frac{1}{2}$ | 26·703 | 56·745 | $13\frac{3}{4}$ | 43·197 | 148·489 |
| $8\frac{5}{8}$ | 27·096 | 58·426 | $13\frac{7}{8}$ | 43·589 | 151·201 |
| $8\frac{3}{4}$ | 27·489 | 60·132 | 14 | 43·982 | 153·938 |
| $8\frac{7}{8}$ | 27·881 | 61·862 | $14\frac{1}{8}$ | 44·375 | 156·699 |
| 9 | 28·274 | 63·617 | $14\frac{1}{4}$ | 44·767 | 159·485 |
| $9\frac{1}{8}$ | 28·667 | 65·396 | $14\frac{3}{8}$ | 45·160 | 162·295 |
| $9\frac{1}{4}$ | 29·059 | 67·200 | $14\frac{1}{2}$ | 45·553 | 165·130 |

| Diameter. | Circumference. | Area. | Diameter. | Circumference. | Area. |
|---|---|---|---|---|---|
| $14\frac{5}{8}$ | 45·945 | 167·989 | $19\frac{7}{8}$ | 62·439 | 310·245 |
| $14\frac{3}{4}$ | 46·338 | 170·873 | 20 | 62·832 | 314·160 |
| $14\frac{7}{8}$ | 46·731 | 173·782 | $20\frac{1}{8}$ | 63·224 | 318·099 |
| 15 | 47·124 | 176·715 | $20\frac{1}{4}$ | 63·617 | 322·063 |
| $15\frac{1}{8}$ | 47·516 | 179·672 | $20\frac{3}{8}$ | 64·010 | 326·051 |
| $15\frac{1}{4}$ | 47·909 | 182·654 | $20\frac{1}{2}$ | 64·402 | 330·064 |
| $15\frac{3}{8}$ | 48·302 | 185·661 | $20\frac{5}{8}$ | 64·795 | 334·101 |
| $15\frac{1}{2}$ | 48·694 | 188·692 | $20\frac{3}{4}$ | 65·188 | 338·163 |
| $15\frac{5}{8}$ | 49·087 | 191·748 | $20\frac{7}{8}$ | 65·580 | 342·250 |
| $15\frac{3}{4}$ | 49·480 | 194·828 | 21 | 65·973 | 346·361 |
| $15\frac{7}{8}$ | 49·872 | 197·933 | $21\frac{1}{8}$ | 66·366 | 350·497 |
| 16 | 50·265 | 201·062 | $21\frac{1}{4}$ | 66·759 | 354·657 |
| $16\frac{1}{8}$ | 50·658 | 204·216 | $21\frac{3}{8}$ | 67·151 | 358·841 |
| $16\frac{1}{4}$ | 51·051 | 207·394 | $21\frac{1}{2}$ | 67·544 | 363·051 |
| $16\frac{3}{8}$ | 51·443 | 210·597 | $21\frac{5}{8}$ | 67·937 | 367·284 |
| $16\frac{1}{2}$ | 51·836 | 213·825 | $21\frac{3}{4}$ | 68·329 | 371·543 |
| $16\frac{5}{8}$ | 52·229 | 217·077 | $21\frac{7}{8}$ | 68·722 | 375·826 |
| $16\frac{3}{4}$ | 52·621 | 220·353 | 22 | 69·115 | 380·133 |
| $16\frac{7}{8}$ | 53·014 | 223·654 | $22\frac{1}{8}$ | 69·507 | 384·465 |
| 17 | 53·407 | 226·980 | $22\frac{1}{4}$ | 69·900 | 388·822 |
| $17\frac{1}{8}$ | 53·799 | 230·330 | $22\frac{3}{8}$ | 70·293 | 393·203 |
| $17\frac{1}{4}$ | 54·192 | 233·705 | $22\frac{1}{2}$ | 70·686 | 397·608 |
| $17\frac{3}{8}$ | 54·585 | 237·104 | $22\frac{5}{8}$ | 71·078 | 402·038 |
| $17\frac{1}{2}$ | 54·978 | 240·528 | $22\frac{3}{4}$ | 71·471 | 406·493 |
| $17\frac{5}{8}$ | 55·370 | 243·977 | $22\frac{7}{8}$ | 71·864 | 410·972 |
| $17\frac{3}{4}$ | 55·763 | 247·450 | 23 | 72·256 | 415·476 |
| $17\frac{7}{8}$ | 56·156 | 250·947 | $23\frac{1}{8}$ | 72·649 | 420·004 |
| 18 | 56·548 | 254·469 | $23\frac{1}{4}$ | 73·042 | 424·557 |
| $18\frac{1}{8}$ | 56·941 | 258·016 | $23\frac{3}{8}$ | 73·434 | 429·135 |
| $18\frac{1}{4}$ | 57·334 | 261·587 | $23\frac{1}{2}$ | 73·827 | 433·731 |
| $18\frac{3}{8}$ | 57·726 | 265·182 | $23\frac{5}{8}$ | 74·220 | 438·363 |
| $18\frac{1}{2}$ | 58·119 | 268·803 | $23\frac{3}{4}$ | 74·613 | 443·014 |
| $18\frac{5}{8}$ | 58·512 | 272·447 | $23\frac{7}{8}$ | 75·005 | 447·699 |
| $18\frac{3}{4}$ | 58·905 | 276·117 | 24 | 75·398 | 452·390 |
| $18\frac{7}{8}$ | 59·297 | 279·811 | $24\frac{1}{8}$ | 75·791 | 457·115 |
| 19 | 59·690 | 283·529 | $24\frac{1}{4}$ | 76·183 | 461·864 |
| $19\frac{1}{8}$ | 60·083 | 287·272 | $24\frac{3}{8}$ | 76·576 | 466·638 |
| $19\frac{1}{4}$ | 60·475 | 291·039 | $24\frac{1}{2}$ | 76·969 | 471·436 |
| $19\frac{3}{8}$ | 60·868 | 294·831 | $24\frac{5}{8}$ | 77·361 | 476·259 |
| $19\frac{1}{2}$ | 61·261 | 298·648 | $24\frac{3}{4}$ | 77·754 | 481·106 |
| $19\frac{5}{8}$ | 61·653 | 302·489 | $24\frac{7}{8}$ | 78·147 | 485·978 |
| $19\frac{3}{4}$ | 62·046 | 306·355 | 25 | 78·540 | 490·875 |

| Diameter. | Circumference. | Area. | Diameter. | Circumference. | Area. |
|---|---|---|---|---|---|
| 25 1/8 | 78·932 | 495·796 | 30 3/8 | 95·426 | 724·641 |
| 25 1/4 | 79·325 | 500·741 | 30 1/2 | 95·818 | 730·618 |
| 25 3/8 | 79·718 | 505·711 | 30 5/8 | 96·211 | 736·619 |
| 25 1/2 | 80·110 | 510·706 | 30 3/4 | 96·604 | 742·644 |
| 25 5/8 | 80·503 | 515·725 | 30 7/8 | 96·996 | 748·694 |
| 25 3/4 | 80·896 | 520·769 | 31 | 97·389 | 754·769 |
| 25 7/8 | 81·288 | 525·837 | 31 1/8 | 97·782 | 760·868 |
| 26 | 81·681 | 530·930 | 31 1/4 | 98·175 | 766·992 |
| 26 1/8 | 82·074 | 536·047 | 31 3/8 | 98·567 | 773·140 |
| 26 1/4 | 82·467 | 541·189 | 31 1/2 | 98·968 | 779·313 |
| 26 3/8 | 82·859 | 546·356 | 31 5/8 | 99·353 | 785·510 |
| 26 1/2 | 83·252 | 551·547 | 31 3/4 | 99·745 | 791·732 |
| 26 5/8 | 83·645 | 556·762 | 31 7/8 | 100·138 | 797·978 |
| 26 3/4 | 84·037 | 562·002 | 32 | 100·531 | 804·249 |
| 26 7/8 | 84·430 | 567·267 | 32 1/8 | 100·924 | 810·545 |
| 27 | 84·823 | 572·556 | 32 1/4 | 101·316 | 816·865 |
| 27 1/8 | 85·215 | 577·870 | 32 3/8 | 101·709 | 823·209 |
| 27 1/4 | 85·608 | 583·208 | 32 1/2 | 102·102 | 829·578 |
| 27 3/8 | 86·001 | 588·571 | 32 5/8 | 102·494 | 835·972 |
| 27 1/2 | 86·394 | 593·958 | 32 3/4 | 102·887 | 842·390 |
| 27 5/8 | 86·786 | 599·370 | 32 7/8 | 103·280 | 848·833 |
| 27 3/4 | 87·179 | 604·807 | 33 | 103·672 | 855·30 |
| 27 7/8 | 87·572 | 610·268 | 33 1/8 | 104·055 | 861·79 |
| 28 | 87·964 | 615·753 | 33 1/4 | 104·458 | 868·30 |
| 28 1/8 | 88·357 | 621·263 | 33 3/8 | 104·850 | 874·84 |
| 28 1/4 | 88·750 | 626·798 | 33 1/2 | 105·243 | 881·41 |
| 28 3/8 | 89·142 | 632·357 | 33 5/8 | 105·636 | 888·00 |
| 28 1/2 | 89·535 | 637·941 | 33 3/4 | 106·029 | 894·61 |
| 28 5/8 | 89·928 | 643·594 | 33 7/8 | 106·421 | 901·25 |
| 28 3/4 | 90·321 | 649·182 | 34 | 106·814 | 907·92 |
| 28 7/8 | 90·713 | 654·839 | 34 1/8 | 107·207 | 914·61 |
| 29 | 91·106 | 660·521 | 34 1/4 | 107·599 | 921·32 |
| 29 1/8 | 91·499 | 666·227 | 34 3/8 | 107·992 | 928·06 |
| 29 1/4 | 91·891 | 671·958 | 34 1/2 | 108·385 | 934·82 |
| 29 3/8 | 92·284 | 677·714 | 34 5/8 | 108·777 | 941·60 |
| 29 1/2 | 92·677 | 683·494 | 34 3/4 | 109·170 | 948·41 |
| 29 5/8 | 93·069 | 689·298 | 34 7/8 | 109·563 | 955·25 |
| 29 3/4 | 93·462 | 695·128 | 35 | 109·956 | 962·11 |
| 29 7/8 | 93·855 | 700·981 | 35 1/8 | 110·348 | 968·99 |
| 30 | 94·248 | 706·860 | 35 1/4 | 110·741 | 975·90 |
| 30 1/8 | 94·640 | 712·762 | 35 3/8 | 111·134 | 982·84 |
| 30 1/4 | 95·033 | 718·690 | 35 1/2 | 111·526 | 989·80 |

| Diameter. | Circumference. | Area. | Diameter. | Circumference. | Area. |
|---|---|---|---|---|---|
| $35\frac{5}{8}$ | 111·919 | 996·78 | $40\frac{7}{8}$ | 128·412 | 1312·21 |
| $35\frac{3}{4}$ | 112·312 | 1003·78 | 41 | 128·805 | 1320·25 |
| $35\frac{7}{8}$ | 112·704 | 1010·82 | $41\frac{1}{8}$ | 129·198 | 1328·32 |
| 36 | 113·097 | 1017·88 | $41\frac{1}{4}$ | 129·591 | 1336·40 |
| $36\frac{1}{8}$ | 113·490 | 1024·95 | $41\frac{3}{8}$ | 129·983 | 1344·51 |
| $36\frac{1}{4}$ | 113·883 | 1032·06 | $41\frac{1}{2}$ | 130·376 | 1352·65 |
| $36\frac{3}{8}$ | 114·275 | 1039·19 | $41\frac{5}{8}$ | 130·769 | 1360·81 |
| $36\frac{1}{2}$ | 114·668 | 1046·35 | $41\frac{3}{4}$ | 131·161 | 1369·00 |
| $36\frac{5}{8}$ | 115·061 | 1053·52 | $41\frac{7}{8}$ | 131·554 | 1377·21 |
| $36\frac{3}{4}$ | 115·453 | 1060·73 | 42 | 131·947 | 1385·44 |
| $36\frac{7}{8}$ | 115·846 | 1067·95 | $42\frac{1}{8}$ | 132·339 | 1393·70 |
| 37 | 116·239 | 1075·21 | $42\frac{1}{4}$ | 132·732 | 1401·98 |
| $37\frac{1}{8}$ | 116·631 | 1082·48 | $42\frac{3}{8}$ | 133·125 | 1410·29 |
| $37\frac{1}{4}$ | 117·024 | 1089·79 | $42\frac{1}{2}$ | 133·518 | 1418·62 |
| $37\frac{3}{8}$ | 117·417 | 1097·11 | $42\frac{5}{8}$ | 133·910 | 1426·98 |
| $37\frac{1}{2}$ | 117·810 | 1104·46 | $42\frac{3}{4}$ | 134·303 | 1435·36 |
| $37\frac{5}{8}$ | 118·202 | 1111·84 | $42\frac{7}{8}$ | 134·696 | 1443·77 |
| $37\frac{3}{4}$ | 118·595 | 1119·24 | 43 | 135·088 | 1452·20 |
| $37\frac{7}{8}$ | 118·988 | 1126·66 | $43\frac{1}{8}$ | 135·481 | 1460·65 |
| 38 | 119·380 | 1134·11 | $43\frac{1}{4}$ | 135·874 | 1469·13 |
| $38\frac{1}{8}$ | 119·773 | 1141·59 | $43\frac{3}{8}$ | 136·266 | 1477·63 |
| $38\frac{1}{4}$ | 120·166 | 1149·08 | $43\frac{1}{2}$ | 136·659 | 1486·17 |
| $38\frac{3}{8}$ | 120·558 | 1156·61 | $43\frac{5}{8}$ | 137·052 | 1494·72 |
| $38\frac{1}{2}$ | 120·951 | 1164·15 | $43\frac{3}{4}$ | 137·445 | 1503·30 |
| $38\frac{5}{8}$ | 121·344 | 1171·73 | $43\frac{7}{8}$ | 137·837 | 1511·90 |
| $38\frac{3}{4}$ | 121·737 | 1179·32 | 44 | 138·230 | 1520·53 |
| $38\frac{7}{8}$ | 122·129 | 1186·94 | $44\frac{1}{8}$ | 138·623 | 1529·18 |
| 39 | 122·522 | 1194·59 | $44\frac{1}{4}$ | 139·015 | 1537·86 |
| $39\frac{1}{8}$ | 122·915 | 1202·26 | $44\frac{3}{8}$ | 139·408 | 1546·55 |
| $39\frac{1}{4}$ | 123·307 | 1209·95 | $44\frac{1}{2}$ | 139·801 | 1555·28 |
| $39\frac{3}{8}$ | 123·700 | 1217·67 | $44\frac{5}{8}$ | 140·193 | 1564·03 |
| $39\frac{1}{2}$ | 124·093 | 1225·42 | $44\frac{3}{4}$ | 140·586 | 1572·81 |
| $39\frac{5}{8}$ | 124·485 | 1233·18 | $44\frac{7}{8}$ | 140·979 | 1581·61 |
| $39\frac{3}{4}$ | 124·878 | 1240·98 | 45 | 141·372 | 1590·43 |
| $39\frac{7}{8}$ | 125·271 | 1248·79 | $45\frac{1}{8}$ | 141·764 | 1599·28 |
| 40 | 125·664 | 1256·64 | $45\frac{1}{4}$ | 142·157 | 1608·15 |
| $40\frac{1}{8}$ | 126·056 | 1264·50 | $45\frac{3}{8}$ | 142·550 | 1617·04 |
| $40\frac{1}{4}$ | 126·449 | 1272·39 | $45\frac{1}{2}$ | 142·942 | 1625·97 |
| $40\frac{3}{8}$ | 126·842 | 1280·31 | $45\frac{5}{8}$ | 143·335 | 1634·92 |
| $40\frac{1}{2}$ | 127·234 | 1288·25 | $45\frac{3}{4}$ | 143·728 | 1643·89 |
| $40\frac{5}{8}$ | 127·627 | 1296·21 | $45\frac{7}{8}$ | 144·120 | 1652·88 |
| $40\frac{3}{4}$ | 128·020 | 1304·20 | 46 | 144·513 | 1661·90 |

| Diameter. | Circumference. | Area. | Diameter. | Circumference. | Area. |
|---|---|---|---|---|---|
| **46⅛** | 144·906 | 1670·95 | **52¾** | 165·719 | 2185·42 |
| **46¼** | 145·299 | 1680·01 | **53** | 166·504 | 2206·18 |
| **46⅜** | 145·691 | 1689·10 | **53¼** | 167·290 | 2227·05 |
| **46½** | 146·084 | 1698·23 | **53½** | 168·075 | 2248·01 |
| **46⅝** | 146·477 | 1707·37 | **53¾** | 168·861 | 2269·06 |
| **46¾** | 146·869 | 1716·54 | **54** | 169·646 | 2290·22 |
| **46⅞** | 147·262 | 1725·73 | **54¼** | 170·431 | 2311·48 |
| **47** | 147·655 | 1734·94 | **54½** | 171·217 | 2332·83 |
| **47⅛** | 148·047 | 1744·18 | **54¾** | 172·002 | 2354·28 |
| **47¼** | 148·440 | 1753·45 | **55** | 172·788 | 2375·83 |
| **47⅜** | 148·833 | 1762·73 | **55¼** | 173·573 | 2397·48 |
| **47½** | 149·226 | 1772·05 | **55½** | 174·358 | 2419·22 |
| **47⅝** | 149·618 | 1781·39 | **55¾** | 175·144 | 2441·07 |
| **47¾** | 150·011 | 1790·76 | **56** | 175·929 | 2463·01 |
| **47⅞** | 150·404 | 1800·14 | **56¼** | 176·715 | 2485·05 |
| **48** | 150·796 | 1809·56 | **56½** | 177·500 | 2507·19 |
| **48⅛** | 151·189 | 1818·99 | **56¾** | 178·285 | 2529·42 |
| **48¼** | 151·582 | 1828·46 | **57** | 179·071 | 2551·76 |
| **48⅜** | 151·974 | 1837·93 | **57¼** | 179·856 | 2574·19 |
| **48½** | 152·367 | 1847·45 | **57½** | 180·642 | 2596·72 |
| **48⅝** | 152·760 | 1856·99 | **57¾** | 181·427 | 2619·35 |
| **48¾** | 153·153 | 1866·55 | **58** | 182·212 | 2642·08 |
| **48⅞** | 153·545 | 1876·13 | **58¼** | 182·998 | 2664·91 |
| **49** | 153·938 | 1885·74 | **58½** | 183·783 | 2687·83 |
| **49⅛** | 154·331 | 1895·37 | **58¾** | 184·569 | 2710·85 |
| **49¼** | 154·723 | 1905·03 | **59** | 185·354 | 2733·97 |
| **49⅜** | 155·116 | 1914·70 | **59¼** | 186·139 | 2757·19 |
| **49½** | 155·509 | 1924·42 | **59½** | 186·925 | 2780·51 |
| **49⅝** | 155·901 | 1934·15 | **59¾** | 187·710 | 2803·92 |
| **49¾** | 156·294 | 1943·91 | **60** | 188·496 | 2827·43 |
| **49⅞** | 156·687 | 1953·69 | **60¼** | 189·281 | 2851·05 |
| **50** | 157·080 | 1963·50 | **60½** | 190·066 | 2874·76 |
| **50¼** | 157·865 | 1983·18 | **60¾** | 190·852 | 2898·56 |
| **50½** | 158·650 | 2002·96 | **61** | 191·637 | 2922·47 |
| **50¾** | 159·436 | 2022·84 | **61¼** | 192·423 | 2946·47 |
| **51** | 160·221 | 2042·82 | **61½** | 193·208 | 2970·57 |
| **51¼** | 161·007 | 2062·90 | **61¾** | 193·993 | 2994·77 |
| **51½** | 161·792 | 2083·07 | **62** | 194·779 | 3019·07 |
| **51¾** | 162·577 | 2103·35 | **62¼** | 195·564 | 3043·47 |
| **52** | 163·363 | 2123·72 | **62½** | 196·350 | 3067·96 |
| **52¼** | 164·148 | 2144·19 | **62¾** | 197·135 | 3092·56 |
| **52½** | 164·934 | 2164·75 | **63** | 197·920 | 3117·25 |

| Diameter. | Circumference. | Area. | Diameter. | Circumference. | Area. |
|---|---|---|---|---|---|
| 63¼ | 198·706 | 3142·04 | 73¾ | 231·693 | 4271·83 |
| 63½ | 199·491 | 3166·92 | 74 | 232·478 | 4300·84 |
| 63¾ | 200·277 | 3191·91 | 74¼ | 233·263 | 4329·95 |
| 64 | 201·062 | 3216·99 | 74½ | 234·049 | 4359·16 |
| 64¼ | 201·847 | 3242·17 | 74¾ | 234·834 | 4388·47 |
| 64½ | 202·633 | 3267·46 | 75 | 235·620 | 4417·86 |
| 64¾ | 203·418 | 3292·83 | 75¼ | 236·405 | 4447·37 |
| 65 | 204·204 | 3318·31 | 75½ | 237·190 | 4476·97 |
| 65¼ | 204·989 | 3343·88 | 75¾ | 237·976 | 4506·67 |
| 65½ | 205·774 | 3369·56 | 76 | 238·761 | 4536·46 |
| 65¾ | 206·560 | 3395·33 | 76¼ | 239·547 | 4566·36 |
| 66 | 207·345 | 3421·19 | 76½ | 240·332 | 4596·35 |
| 66¼ | 208·131 | 3447·16 | 76¾ | 241·117 | 4626·44 |
| 66½ | 208·916 | 3473·23 | 77 | 241·903 | 4656·63 |
| 66¾ | 209·701 | 3499·39 | 77¼ | 242·688 | 4686·92 |
| 67 | 210·487 | 3525·66 | 77½ | 243·474 | 4717·30 |
| 67¼ | 211·272 | 3552·01 | 77¾ | 244·259 | 4747·79 |
| 67½ | 212·058 | 3578·47 | 78 | 245·044 | 4778·36 |
| 67¾ | 212·843 | 3605·03 | 78¼ | 245·830 | 4809·05 |
| 68 | 213·628 | 3631·68 | 78½ | 246·615 | 4839·83 |
| 68¼ | 214·414 | 3658·44 | 78¾ | 247·401 | 4870·70 |
| 68½ | 215·199 | 3685·29 | 79 | 248·186 | 4901·68 |
| 68¾ | 215·985 | 3712·24 | 79¼ | 248·971 | 4932·75 |
| 69 | 216·770 | 3739·28 | 79½ | 249·757 | 4963·92 |
| 69¼ | 217·555 | 3766·43 | 79¾ | 250·542 | 4995·19 |
| 69½ | 218·341 | 3793·67 | 80 | 251·328 | 5026·55 |
| 69¾ | 219·126 | 3821·02 | 80¼ | 252·113 | 5058·00 |
| 70 | 219·912 | 3848·45 | 80½ | 252·898 | 5089·58 |
| 70¼ | 220·697 | 3875·99 | 80¾ | 253·683 | 5121·22 |
| 70½ | 221·482 | 3903·63 | 81 | 254·469 | 5153·00 |
| 70¾ | 222·268 | 3931·36 | 81¼ | 255·254 | 5184·84 |
| 71 | 223·053 | 3959·19 | 81½ | 256·040 | 5216·82 |
| 71¼ | 223·839 | 3987·13 | 81¾ | 256·825 | 5248·84 |
| 71½ | 224·624 | 4015·16 | 82 | 257·611 | 5281·02 |
| 71¾ | 225·409 | 4043·28 | 82¼ | 258·396 | 5313·28 |
| 72 | 226·195 | 4071·50 | 82½ | 259·182 | 5345·62 |
| 72¼ | 226·980 | 4099·83 | 82¾ | 259·967 | 5378·04 |
| 72½ | 227·766 | 4128·25 | 83 | 260·752 | 5410·61 |
| 72¾ | 228·551 | 4156·77 | 83¼ | 261·537 | 5443·24 |
| 73 | 229·336 | 4185·39 | 83½ | 262·323 | 5476·00 |
| 73 | 230·122 | 4214·11 | 83¾ | 263·108 | 5508·84 |
| 73 | 230·907 | 4242·92 | 84 | 263·894 | 5541·77 |

| Diameter. | Circumference. | Area. | Diameter. | Circumference. | Area. |
|---|---|---|---|---|---|
| 84¼ | 264·679 | 5574·80 | 94¾ | 297·666 | 7050·92 |
| 84½ | 265·465 | 5607·95 | 95 | 298·452 | 7088·22 |
| 84¾ | 266·250 | 5641·16 | 95¼ | 299·237 | 7125·56 |
| 85 | 267·035 | 5674·51 | 95½ | 300·022 | 7163·04 |
| 85¼ | 267·821 | 5707·92 | 95¾ | 300·807 | 7200·56 |
| 85½ | 268·606 | 5741·47 | 96 | 301·593 | 7238·23 |
| 85¾ | 269·392 | 5775·09 | 96¼ | 302·378 | 7275·96 |
| 86 | 270·177 | 5808·80 | 96½ | 302·164 | 7313·84 |
| 86¼ | 270·962 | 5842·60 | 96¾ | 303·948 | 7351·72 |
| 86½ | 271·748 | 5876·55 | 97 | 304·734 | 7389·81 |
| 86¾ | 272·533 | 5910·52 | 97¼ | 305·520 | 7427·96 |
| 87 | 273·319 | 5944·68 | 97½ | 306·306 | 7474·20 |
| 87¼ | 274·104 | 5978·88 | 97¾ | 307·090 | 7504·52 |
| 87½ | 274·890 | 6013·21 | 98 | 307·876 | 7542·96 |
| 87¾ | 275·675 | 6047·60 | 98¼ | 308·662 | 7581·48 |
| 88 | 276·460 | 6082·12 | 98½ | 309·446 | 7620·12 |
| 88¼ | 277·245 | 6116·72 | 98¾ | 310·232 | 7658·80 |
| 88½ | 278·031 | 6151·44 | 99 | 311·018 | 7697·69 |
| 88¾ | 278·816 | 6186·20 | 99¼ | 311·802 | 7736·60 |
| 89 | 279·602 | 6221·14 | 99½ | 312·588 | 7775·64 |
| 89¼ | 280·387 | 6256·12 | 99¾ | 313·374 | 7814·76 |
| 89½ | 281·173 | 6291·25 | 100 | 314·159 | 7853·98 |
| 89¾ | 281·958 | 6326·44 | 100½ | 315·730 | 7938·72 |
| 90 | 282·744 | 6361·73 | 101 | 317·301 | 8011·85 |
| 90¼ | 283·529 | 6399·12 | 101½ | 318·872 | 8091·36 |
| 90½ | 284·314 | 6432·62 | 102 | 320·442 | 8171·28 |
| 90¾ | 285·099 | 6468·16 | 102½ | 322·014 | 8251·60 |
| 91 | 285·885 | 6503·88 | 103 | 323·584 | 8332·29 |
| 91¼ | 286·670 | 6539·68 | 103½ | 325·154 | 8413·40 |
| 91½ | 287·456 | 6573·56 | 104 | 326·726 | 8494·87 |
| 91¾ | 288·242 | 6611·52 | 104½ | 328·296 | 8576·76 |
| 92 | 289·027 | 6647·61 | 105 | 329·867 | 8659·01 |
| 92¼ | 289·812 | 6683·80 | 105½ | 331·438 | 8741·68 |
| 92½ | 290·598 | 6720·07 | 106 | 333·009 | 8824·73 |
| 92¾ | 291·383 | 6756·40 | 106½ | 334·580 | 8908·20 |
| 93 | 292·168 | 6792·91 | 107 | 336·150 | 8992·02 |
| 93¼ | 292·953 | 6829·48 | 107½ | 337·722 | 9076·24 |
| 93½ | 293·739 | 6866·16 | 108 | 339·292 | 9160·88 |
| 93¾ | 294·524 | 6882·92 | 108½ | 340·862 | 9245·92 |
| 94 | 295·310 | 6939·78 | 109 | 342·434 | 9331·32 |
| 94¼ | 296·095 | 6976·72 | 109½ | 344·004 | 9417·12 |
| 94½ | 296·881 | 7013·81 | 110 | 345·575 | 9503·32 |

| Diameter. | Circumference. | Area. | Diameter. | Circumference. | Area. |
|---|---|---|---|---|---|
| 110½ | 347·146 | 9589·92 | 115½ | 362·854 | 10477·40 |
| 111 | 348·717 | 9676·89 | 116 | 364·425 | 10568·32 |
| 111½ | 350·288 | 9764·28 | 116½ | 365·996 | 10659·64 |
| 112 | 351·858 | 9852·03 | 117 | 367·566 | 10751·32 |
| 112½ | 353·430 | 9940·20 | 117½ | 369·138 | 10843·40 |
| 113 | 355·000 | 10028·75 | 118 | 370·708 | 10935·88 |
| 113½ | 356·570 | 10117·68 | 118½ | 372·278 | 11028·76 |
| 114 | 358·142 | 10207·03 | 119 | 373·849 | 11122·02 |
| 114½ | 359·712 | 10296·76 | 119½ | 375·420 | 11215·68 |
| 115 | 361·283 | 10386·89 | 120 | 376·991 | 11309·73 |

TABLE 3.—RECIPROCALS OF NUMBERS, FROM 1 TO 1,000.*

| No. | Reciprocal. | No. | Reciprocal. | No. | Reciprocal. | No. | Reciprocal. |
|---|---|---|---|---|---|---|---|
| 1 | 1·000000 | 25 | ·040000 | 49 | ·020408 | 73 | ·013699 |
| 2 | ·500000 | 26 | ·038462 | 50 | ·020000 | 74 | ·013514 |
| 3 | ·333333 | 27 | ·037037 | 51 | ·019608 | 75 | ·013333 |
| 4 | ·250000 | 28 | ·035714 | 52 | ·019231 | 76 | ·013158 |
| 5 | ·200000 | 29 | ·034483 | 53 | ·018868 | 77 | ·012987 |
| 6 | ·166667 | 30 | ·033333 | 54 | ·018519 | 78 | ·012821 |
| 7 | ·142857 | 31 | ·032258 | 55 | ·018182 | 79 | ·012658 |
| 8 | ·125000 | 32 | ·031250 | 56 | ·017857 | 80 | ·012500 |
| 9 | ·111111 | 33 | ·030303 | 57 | ·017544 | 81 | ·012346 |
| 10 | ·100000 | 34 | ·029412 | 58 | ·017241 | 82 | ·012195 |
| 11 | ·090909 | 35 | ·028571 | 59 | ·016949 | 83 | ·012048 |
| 12 | ·083333 | 36 | ·027778 | 60 | ·016667 | 84 | ·011905 |
| 13 | ·076923 | 37 | ·027027 | 61 | ·016393 | 85 | ·011765 |
| 14 | ·071429 | 38 | ·026316 | 62 | ·016129 | 86 | ·011628 |
| 15 | ·066667 | 39 | ·025641 | 63 | ·015873 | 87 | ·011494 |
| 16 | ·062500 | 40 | ·025000 | 64 | ·015625 | 88 | ·011364 |
| 17 | ·058824 | 41 | ·024390 | 65 | ·015385 | 89 | ·011236 |
| 18 | ·055556 | 42 | ·023810 | 66 | ·015152 | 90 | ·011111 |
| 19 | ·052632 | 43 | ·023256 | 67 | ·014925 | 91 | ·010989 |
| 20 | ·050000 | 44 | ·022727 | 68 | ·014706 | 92 | ·010870 |
| 21 | ·047619 | 45 | ·022222 | 69 | ·014493 | 93 | ·010753 |
| 22 | ·045455 | 46 | ·021739 | 70 | ·014286 | 94 | ·010638 |
| 23 | ·043478 | 47 | ·021277 | 71 | ·014085 | 95 | ·010526 |
| 24 | ·041667 | 48 | ·020833 | 72 | ·013889 | 96 | ·010417 |

* See Introduction, *ante*, p. 2.

| No. | Reci-procal. | No. | Reci-procal. | No. | Reci-procal. | No. | Reci-procal. |
|---|---|---|---|---|---|---|---|
| **97** | ·010309 | **139** | ·007194 | **181** | ·005525 | **223** | ·004484 |
| **98** | ·010204 | **140** | ·007143 | **182** | ·005495 | **224** | ·004464 |
| **99** | ·010101 | **141** | ·007092 | **183** | ·005464 | **225** | ·004444 |
| **100** | ·010000 | **142** | ·007042 | **184** | ·005435 | **226** | ·004425 |
| **101** | ·009901 | **143** | ·006993 | **185** | ·005405 | **227** | ·004405 |
| **102** | ·009804 | **144** | ·006944 | **186** | ·005376 | **228** | ·004386 |
| **103** | ·009709 | **145** | ·006897 | **187** | ·005348 | **229** | ·004367 |
| **104** | ·009615 | **146** | ·006849 | **188** | ·005319 | **230** | ·004348 |
| **105** | ·009524 | **147** | ·006803 | **189** | ·005291 | **231** | ·004329 |
| **106** | ·009434 | **148** | ·006757 | **190** | ·005263 | **232** | ·004310 |
| **107** | ·009346 | **149** | ·006711 | **191** | ·005236 | **233** | ·004292 |
| **108** | ·009259 | **150** | ·006667 | **192** | ·005208 | **234** | ·004274 |
| **109** | ·009174 | **151** | ·006623 | **193** | ·005181 | **235** | ·004255 |
| **110** | ·009091 | **152** | ·006579 | **194** | ·005155 | **236** | ·004237 |
| **111** | ·009009 | **153** | ·006536 | **195** | ·005128 | **237** | ·004219 |
| **112** | ·008929 | **154** | ·006494 | **196** | ·005102 | **238** | ·004202 |
| **113** | ·008850 | **155** | ·006452 | **197** | ·005076 | **239** | ·004184 |
| **114** | ·008772 | **156** | ·006410 | **198** | ·005051 | **240** | ·004167 |
| **115** | ·008696 | **157** | ·006369 | **199** | ·005025 | **241** | ·004149 |
| **116** | ·008621 | **158** | ·006329 | **200** | ·005000 | **242** | ·004132 |
| **117** | ·008547 | **159** | ·006289 | **201** | ·004975 | **243** | ·004115 |
| **118** | ·008475 | **160** | ·006250 | **202** | ·004950 | **244** | ·004098 |
| **119** | ·008403 | **161** | ·006211 | **203** | ·004926 | **245** | ·004082 |
| **120** | ·008333 | **162** | ·006173 | **204** | ·004902 | **246** | ·004065 |
| **121** | ·008264 | **163** | ·006135 | **205** | ·004878 | **247** | ·004049 |
| **122** | ·008197 | **164** | ·006098 | **206** | ·004854 | **248** | ·004032 |
| **123** | ·008130 | **165** | ·006061 | **207** | ·004831 | **249** | ·004016 |
| **124** | ·008065 | **166** | ·006024 | **208** | ·004808 | **250** | ·004000 |
| **125** | ·008000 | **167** | ·005988 | **209** | ·004785 | **251** | ·003984 |
| **126** | ·007937 | **168** | ·005952 | **210** | ·004762 | **252** | ·003968 |
| **127** | ·007874 | **169** | ·005917 | **211** | ·004739 | **253** | ·003953 |
| **128** | ·007813 | **170** | ·005882 | **212** | ·004717 | **254** | ·003937 |
| **129** | ·007752 | **171** | ·005848 | **213** | ·004695 | **255** | ·003922 |
| **130** | ·007692 | **172** | ·005814 | **214** | ·004673 | **256** | ·003906 |
| **131** | ·007634 | **173** | ·005780 | **215** | ·004651 | **257** | ·003891 |
| **132** | ·007576 | **174** | ·005747 | **216** | ·004630 | **258** | ·003876 |
| **133** | ·007519 | **175** | ·005714 | **217** | ·004608 | **259** | ·003861 |
| **134** | ·007463 | **176** | ·005682 | **218** | ·004587 | **260** | ·003846 |
| **135** | ·007407 | **177** | ·005650 | **219** | ·004566 | **261** | ·003831 |
| **136** | ·007353 | **178** | ·005618 | **220** | ·004545 | **262** | ·003817 |
| **137** | ·007299 | **179** | ·005587 | **221** | ·004525 | **263** | ·003802 |
| **138** | ·007246 | **180** | ·005556 | **222** | ·004505 | **264** | ·003788 |

| No. | Reciprocal. | No. | Reciprocal. | No. | Reciprocal. | No. | Reciprocal. |
|---|---|---|---|---|---|---|---|
| **265** | ·003774 | **307** | ·003257 | **349** | ·002865 | **391** | ·002558 |
| **266** | ·003759 | **308** | ·003247 | **350** | ·002857 | **392** | ·002551 |
| **267** | ·003745 | **309** | ·003236 | **351** | ·002849 | **393** | ·002545 |
| **268** | ·003731 | **310** | ·003226 | **352** | ·002841 | **394** | ·002538 |
| **269** | ·003717 | **311** | ·003215 | **353** | ·002833 | **395** | ·002532 |
| **270** | ·003704 | **312** | ·003205 | **354** | ·002825 | **396** | ·002525 |
| **271** | ·003690 | **313** | ·003195 | **355** | ·002817 | **397** | ·002519 |
| **272** | ·003676 | **314** | ·003185 | **356** | ·002809 | **398** | ·002513 |
| **273** | ·003663 | **315** | ·003175 | **357** | ·002801 | **399** | ·002506 |
| **274** | ·003650 | **316** | ·003165 | **358** | ·002793 | **400** | ·002500 |
| **275** | ·003636 | **317** | ·003155 | **359** | ·002786 | **401** | ·002494 |
| **276** | ·003623 | **318** | ·003145 | **360** | ·002778 | **402** | ·002488 |
| **277** | ·003610 | **319** | ·003135 | **361** | ·002770 | **403** | ·002481 |
| **278** | ·003597 | **320** | ·003125 | **362** | ·002762 | **404** | ·002475 |
| **279** | ·003584 | **321** | ·003115 | **363** | ·002755 | **405** | ·002469 |
| **280** | ·003571 | **322** | ·003106 | **364** | ·002747 | **406** | ·002463 |
| **281** | ·003559 | **323** | ·003096 | **365** | ·002740 | **407** | ·002457 |
| **282** | ·003546 | **324** | ·003086 | **366** | ·002732 | **408** | ·002451 |
| **283** | ·003534 | **325** | ·003077 | **367** | ·002725 | **409** | ·002445 |
| **284** | ·003522 | **326** | ·003067 | **368** | ·002717 | **410** | ·002439 |
| **285** | ·003509 | **327** | ·003058 | **369** | ·002710 | **411** | ·002433 |
| **286** | ·003497 | **328** | ·003049 | **370** | ·002703 | **412** | ·002427 |
| **287** | ·003484 | **329** | ·003040 | **371** | ·002695 | **413** | ·002421 |
| **288** | ·003472 | **330** | ·003030 | **372** | ·002688 | **414** | ·002415 |
| **289** | ·003460 | **331** | ·003021 | **373** | ·002681 | **415** | ·002410 |
| **290** | ·003448 | **332** | ·003012 | **374** | ·002674 | **416** | ·002407 |
| **291** | ·003436 | **333** | ·003003 | **375** | ·002667 | **417** | ·002398 |
| **292** | ·003425 | **334** | ·002994 | **376** | ·002660 | **418** | ·002392 |
| **293** | ·003413 | **335** | ·002985 | **377** | ·002653 | **419** | ·002387 |
| **294** | ·003401 | **336** | ·002976 | **378** | ·002646 | **420** | ·002381 |
| **295** | ·003390 | **337** | ·002967 | **379** | ·002639 | **421** | ·002375 |
| **296** | ·003378 | **338** | ·002959 | **380** | ·002632 | **422** | ·002370 |
| **297** | ·003367 | **339** | ·002950 | **381** | ·002625 | **423** | ·002364 |
| **298** | ·003356 | **340** | ·002941 | **382** | ·002618 | **424** | ·002358 |
| **299** | ·003344 | **341** | ·002933 | **383** | ·002611 | **425** | ·002353 |
| **300** | ·003333 | **342** | ·002924 | **384** | ·002604 | **426** | ·002347 |
| **301** | ·003322 | **343** | ·002915 | **385** | ·002597 | **427** | ·002342 |
| **302** | ·003311 | **344** | ·002907 | **386** | ·002591 | **428** | ·002336 |
| **303** | ·003301 | **345** | ·002899 | **387** | ·002584 | **429** | ·002331 |
| **304** | ·003289 | **346** | ·002890 | **388** | ·002577 | **430** | ·002326 |
| **305** | ·003279 | **347** | ·002882 | **389** | ·002571 | **431** | ·002320 |
| **306** | ·003268 | **348** | ·002874 | **390** | ·002564 | **432** | ·002315 |

| No. | Reciprocal. | No. | Reciprocal. | No. | Reciprocal. | No. | Reciprocal. |
|---|---|---|---|---|---|---|---|
| 433 | ·002309 | 475 | ·002105 | 517 | ·001934 | 559 | ·001789 |
| 434 | ·002304 | 476 | ·002101 | 518 | ·001931 | 560 | ·001786 |
| 435 | ·002299 | 477 | ·002096 | 519 | ·001927 | 561 | ·001783 |
| 436 | ·002294 | 478 | ·002092 | 520 | ·001923 | 562 | ·001779 |
| 437 | ·002288 | 479 | ·002088 | 521 | ·001919 | 563 | ·001776 |
| 438 | ·002283 | 480 | ·002083 | 522 | ·001916 | 564 | ·001773 |
| 439 | ·002278 | 481 | ·002079 | 523 | ·001912 | 565 | ·001770 |
| 440 | ·002273 | 482 | ·002075 | 524 | ·001908 | 566 | ·001767 |
| 441 | ·002268 | 483 | ·002070 | 525 | ·001905 | 567 | ·001764 |
| 442 | ·002262 | 484 | ·002066 | 526 | ·001901 | 568 | ·001761 |
| 443 | ·002257 | 485 | ·002062 | 527 | ·001898 | 569 | ·001757 |
| 444 | ·002252 | 486 | ·002058 | 528 | ·001894 | 570 | ·001754 |
| 445 | ·002247 | 487 | ·002053 | 529 | ·001890 | 571 | ·001751 |
| 446 | ·002242 | 488 | ·002049 | 530 | ·001887 | 572 | ·001748 |
| 447 | ·002237 | 489 | ·002045 | 531 | ·001883 | 573 | ·001745 |
| 448 | ·002232 | 490 | ·002041 | 532 | ·001880 | 574 | ·001742 |
| 449 | ·002227 | 491 | ·002037 | 533 | ·001876 | 575 | ·001739 |
| 450 | ·002222 | 492 | ·002033 | 534 | ·001873 | 576 | ·001736 |
| 451 | ·002217 | 493 | ·002028 | 535 | ·001869 | 577 | ·001733 |
| 452 | ·002212 | 494 | ·002024 | 536 | ·001866 | 578 | ·001730 |
| 453 | ·002208 | 495 | ·002020 | 537 | ·001862 | 579 | ·001727 |
| 454 | ·002203 | 496 | ·002016 | 538 | ·001859 | 580 | ·001724 |
| 455 | ·002198 | 497 | ·002012 | 539 | ·001855 | 581 | ·001721 |
| 456 | ·002193 | 498 | ·002008 | 540 | ·001852 | 582 | ·001718 |
| 457 | ·002188 | 499 | ·002004 | 541 | ·001848 | 583 | ·001715 |
| 458 | ·002183 | 500 | ·002000 | 542 | ·001845 | 584 | ·001712 |
| 459 | ·002179 | 501 | ·001996 | 543 | ·001842 | 585 | ·001709 |
| 460 | ·002174 | 502 | ·001992 | 544 | ·001838 | 586 | ·001706 |
| 461 | ·002169 | 503 | ·001988 | 545 | ·001835 | 587 | ·001704 |
| 462 | ·002165 | 504 | ·001984 | 546 | ·001832 | 588 | ·001701 |
| 463 | ·002160 | 505 | ·001980 | 547 | ·001828 | 589 | ·001698 |
| 464 | ·002155 | 506 | ·001976 | 548 | ·001825 | 590 | ·001695 |
| 465 | ·002151 | 507 | ·001972 | 549 | ·001821 | 591 | ·001692 |
| 466 | ·002146 | 508 | ·001969 | 550 | ·001818 | 592 | ·001689 |
| 467 | ·002141 | 509 | ·001965 | 551 | ·001815 | 593 | ·001686 |
| 468 | ·002137 | 510 | ·001961 | 552 | ·001812 | 594 | ·001684 |
| 469 | ·002132 | 511 | ·001957 | 553 | ·001808 | 595 | ·001681 |
| 470 | ·002128 | 512 | ·001953 | 554 | ·001805 | 596 | ·001678 |
| 471 | ·002123 | 513 | ·001949 | 555 | ·001802 | 597 | ·001675 |
| 472 | ·002119 | 514 | ·001946 | 556 | ·001799 | 598 | ·001672 |
| 473 | ·002114 | 515 | ·001942 | 557 | ·001795 | 599 | ·001669 |
| 474 | ·002110 | 516 | ·001938 | 558 | ·001792 | 600 | ·001667 |

| No. | Reciprocal. | No. | Reciprocal. | No. | Reciprocal. | No. | Reciprocal. |
|---|---|---|---|---|---|---|---|
| 601 | ·001664 | 643 | ·001555 | 685 | ·001460 | 727 | ·001376 |
| 602 | ·001661 | 644 | ·001553 | 686 | ·001458 | 728 | ·001374 |
| 603 | ·001658 | 645 | ·001550 | 687 | ·001456 | 729 | ·001372 |
| 604 | ·001656 | 646 | ·001548 | 688 | ·001453 | 730 | ·001370 |
| 605 | ·001653 | 647 | ·001546 | 689 | ·001451 | 731 | ·001368 |
| 606 | ·001650 | 648 | ·001543 | 690 | ·001449 | 732 | ·001366 |
| 607 | ·001647 | 649 | ·001541 | 691 | ·001447 | 733 | ·001364 |
| 608 | ·001645 | 650 | ·001538 | 692 | ·001445 | 734 | ·001362 |
| 609 | ·001642 | 651 | ·001536 | 693 | ·001443 | 735 | ·001361 |
| 610 | ·001639 | 652 | ·001534 | 694 | ·001441 | 736 | ·001359 |
| 611 | ·001637 | 653 | ·001531 | 695 | ·001439 | 737 | ·001357 |
| 612 | ·001634 | 654 | ·001529 | 696 | ·001437 | 738 | ·001355 |
| 613 | ·001631 | 655 | ·001527 | 697 | ·001435 | 739 | ·001353 |
| 614 | ·001629 | 656 | ·001524 | 698 | ·001433 | 740 | ·001351 |
| 615 | ·001626 | 657 | ·001522 | 699 | ·001431 | 741 | ·001350 |
| 616 | ·001623 | 658 | ·001520 | 700 | ·001429 | 742 | ·001348 |
| 617 | ·001621 | 659 | ·001517 | 701 | ·001427 | 743 | ·001346 |
| 618 | ·001618 | 660 | ·001515 | 702 | ·001425 | 744 | ·001344 |
| 619 | ·001616 | 661 | ·001513 | 703 | ·001422 | 745 | ·001342 |
| 620 | ·001613 | 662 | ·001511 | 704 | ·001420 | 746 | ·001340 |
| 621 | ·001610 | 663 | ·001508 | 705 | ·001418 | 747 | ·001339 |
| 622 | ·001608 | 664 | ·001506 | 706 | ·001416 | 748 | ·001337 |
| 623 | ·001605 | 665 | ·001504 | 707 | ·001414 | 749 | ·001335 |
| 624 | ·001603 | 666 | ·001502 | 708 | ·001412 | 750 | ·001333 |
| 625 | ·001600 | 667 | ·001499 | 709 | ·001410 | 751 | ·001332 |
| 626 | ·001597 | 668 | ·001497 | 710 | ·001408 | 752 | ·001330 |
| 627 | ·001595 | 669 | ·001495 | 711 | ·001406 | 753 | ·001328 |
| 628 | ·001592 | 670 | ·001493 | 712 | ·001404 | 754 | ·001326 |
| 629 | ·001590 | 671 | ·001490 | 713 | ·001403 | 755 | ·001325 |
| 630 | ·001587 | 672 | ·001488 | 714 | ·001401 | 756 | ·001323 |
| 631 | ·001585 | 673 | ·001486 | 715 | ·001399 | 757 | ·001321 |
| 632 | ·001582 | 674 | ·001484 | 716 | ·001397 | 758 | ·001319 |
| 633 | ·001580 | 675 | ·001481 | 717 | ·001395 | 759 | ·001318 |
| 634 | ·001577 | 676 | ·001479 | 718 | ·001393 | 760 | ·001316 |
| 635 | ·001575 | 677 | ·001477 | 719 | ·001391 | 761 | ·001314 |
| 636 | ·001572 | 678 | ·001475 | 720 | ·001389 | 762 | ·001312 |
| 637 | ·001570 | 679 | ·001473 | 721 | ·001387 | 763 | ·001311 |
| 638 | ·001567 | 680 | ·001471 | 722 | ·001385 | 764 | ·001309 |
| 639 | ·001565 | 681 | ·001468 | 723 | ·001383 | 765 | ·001307 |
| 640 | ·001563 | 682 | ·001466 | 724 | ·001381 | 766 | ·001305 |
| 641 | ·001560 | 683 | ·001464 | 725 | ·001379 | 767 | ·001304 |
| 642 | ·001558 | 684 | ·001462 | 726 | ·001377 | 768 | ·001302 |

| No. | Reci-procal. | No. | Reci-procal. | No. | Reci-procal. | No. | Reci-procal. |
|---|---|---|---|---|---|---|---|
| 769 | ·001300 | 811 | ·001233 | 853 | ·001172 | 895 | ·001118 |
| 770 | ·001299 | 812 | ·001232 | 854 | ·001171 | 896 | ·001116 |
| 771 | ·001297 | 813 | ·001230 | 855 | ·001170 | 897 | ·001115 |
| 772 | ·001295 | 814 | ·001229 | 856 | ·001168 | 898 | ·001114 |
| 773 | ·001294 | 815 | ·001227 | 857 | ·001167 | 899 | ·001112 |
| 774 | ·001292 | 816 | ·001225 | 858 | ·001166 | 900 | ·001111 |
| 775 | ·001290 | 817 | ·001224 | 859 | ·001164 | 901 | ·001110 |
| 776 | ·001289 | 818 | ·001222 | 860 | ·001163 | 902 | ·001109 |
| 777 | ·001287 | 819 | ·001221 | 861 | ·001161 | 903 | ·001107 |
| 778 | ·001285 | 820 | ·001220 | 862 | ·001160 | 904 | ·001106 |
| 779 | ·001284 | 821 | ·001218 | 863 | ·001159 | 905 | ·001105 |
| 780 | ·001282 | 822 | ·001217 | 864 | ·001157 | 906 | ·001104 |
| 781 | ·001280 | 823 | ·001215 | 865 | ·001156 | 907 | ·001103 |
| 782 | ·001279 | 824 | ·001214 | 866 | ·001155 | 908 | ·001101 |
| 783 | ·001277 | 825 | ·001212 | 867 | ·001153 | 909 | ·001100 |
| 784 | ·001276 | 826 | ·001211 | 868 | ·001152 | 910 | ·001099 |
| 785 | ·001274 | 827 | ·001209 | 869 | ·001151 | 911 | ·001098 |
| 786 | ·001272 | 828 | ·001208 | 870 | ·001149 | 912 | ·001096 |
| 787 | ·001271 | 829 | ·001206 | 871 | ·001148 | 913 | ·001095 |
| 788 | ·001269 | 830 | ·001205 | 872 | ·001147 | 914 | ·001094 |
| 789 | ·001267 | 831 | ·001203 | 873 | ·001145 | 915 | ·001093 |
| 790 | ·001266 | 832 | ·001202 | 874 | ·001144 | 916 | ·001092 |
| 791 | ·001264 | 833 | ·001200 | 875 | ·001143 | 917 | ·001091 |
| 792 | ·001263 | 834 | ·001199 | 876 | ·001142 | 918 | ·001089 |
| 793 | ·001261 | 835 | ·001198 | 877 | ·001140 | 919 | ·001088 |
| 794 | ·001259 | 836 | ·001196 | 878 | ·001139 | 920 | ·001087 |
| 795 | ·001258 | 837 | ·001195 | 879 | ·001138 | 921 | ·001086 |
| 796 | ·001256 | 838 | ·001193 | 880 | ·001136 | 922 | ·001085 |
| 797 | ·001255 | 839 | ·001192 | 881 | ·001135 | 923 | ·001083 |
| 798 | ·001253 | 840 | ·001190 | 882 | ·001134 | 924 | ·001082 |
| 799 | ·001251 | 841 | ·001189 | 883 | ·001133 | 925 | ·001081 |
| 800 | ·001250 | 842 | ·001188 | 884 | ·001131 | 926 | ·001080 |
| 801 | ·001248 | 843 | ·001186 | 885 | ·001130 | 927 | ·001079 |
| 802 | ·001247 | 844 | ·001185 | 886 | ·001129 | 928 | ·001078 |
| 803 | ·001245 | 845 | ·001183 | 887 | ·001127 | 929 | ·001076 |
| 804 | ·001244 | 846 | ·091182 | 888 | ·001126 | 930 | ·001075 |
| 805 | ·001242 | 847 | ·001181 | 889 | ·001125 | 931 | ·001074 |
| 806 | ·001241 | 848 | ·001179 | 890 | ·001124 | 932 | ·001073 |
| 807 | ·001239 | 849 | ·001178 | 891 | ·001122 | 933 | ·001072 |
| 808 | ·001238 | 850 | ·001176 | 892 | ·001121 | 934 | ·001071 |
| 809 | ·001236 | 851 | ·001175 | 893 | ·001120 | 935 | ·001070 |
| 810 | ·001235 | 852 | ·001174 | 894 | ·001119 | 936 | ·001068 |

| No. | Reciprocal. | No. | Reciprocal. | No. | Reciprocal. | No. | Reciprocal. |
|---|---|---|---|---|---|---|---|
| **937** | ·001067 | **953** | ·001049 | **969** | ·001032 | **985** | ·001015 |
| **938** | ·001066 | **954** | ·001048 | **970** | ·001031 | **986** | ·001014 |
| **939** | ·001065 | **955** | ·001047 | **971** | ·001030 | **987** | ·001013 |
| **940** | ·001064 | **956** | ·001046 | **972** | ·001029 | **988** | ·001012 |
| **941** | ·001063 | **957** | ·001045 | **973** | ·001028 | **989** | ·001011 |
| **942** | ·001062 | **958** | ·001044 | **974** | ·001027 | **990** | ·001010 |
| **943** | ·001060 | **959** | ·001043 | **975** | ·001026 | **991** | ·001009 |
| **944** | ·001059 | **960** | ·001042 | **976** | ·001025 | **992** | ·001008 |
| **945** | ·001058 | **961** | ·001041 | **977** | ·001024 | **993** | ·001007 |
| **946** | ·001057 | **962** | ·001040 | **978** | ·001022 | **994** | ·001006 |
| **947** | ·001056 | **963** | ·001038 | **979** | ·001021 | **995** | ·001005 |
| **948** | ·001055 | **964** | ·001037 | **980** | ·001020 | **996** | ·001004 |
| **949** | ·001054 | **965** | ·001036 | **981** | ·001019 | **997** | ·001003 |
| **950** | ·001053 | **966** | ·001035 | **982** | ·001018 | **998** | ·001002 |
| **951** | ·001052 | **967** | ·001034 | **983** | ·001017 | **999** | ·001001 |
| **952** | ·001050 | **968** | ·001033 | **984** | ·001016 | **1000** | ·001000 |

## TABLE 3A.—RHUMBS, OR POINTS OF THE COMPASS.

| Points. | Angles. | NORTH. | NORTH. | SOUTH. | SOUTH. |
|---|---|---|---|---|---|
| $\frac{1}{4}$ | 2° 48′ 45″ | N $\frac{1}{4}$ E | N $\frac{1}{4}$ W | S $\frac{1}{4}$ E | S $\frac{1}{4}$ W |
| $\frac{1}{2}$ | 5 37 30 | N $\frac{1}{2}$ E | N $\frac{1}{2}$ W | S $\frac{1}{2}$ E | S $\frac{1}{2}$ W |
| $\frac{3}{4}$ | 8 26 15 | N $\frac{3}{4}$ E | N $\frac{3}{4}$ W | S $\frac{3}{4}$ E | S $\frac{3}{4}$ W |
| 1 | 11 15 0 | N by E | N by W | S by E | S by W |
| $1\frac{1}{2}$ | 16 52 30 | N by E $\frac{1}{2}$ E | N by W $\frac{1}{2}$ W | S by E $\frac{1}{2}$ E | S by W $\frac{1}{2}$ W |
| 2 | 22 30 0 | NNE | NNW | SSE | SSW |
| $2\frac{1}{2}$ | 28 7 30 | NNE $\frac{1}{2}$ E | NNW $\frac{1}{2}$ W | SSE $\frac{1}{2}$ E | SSW $\frac{1}{2}$ W |
| 3 | 33 45 0 | NE by N | NW by N | SE by S | SW by S |
| $3\frac{1}{2}$ | 39 22 30 | NE $\frac{1}{2}$ N | NW $\frac{1}{2}$ N | SE $\frac{1}{2}$ S | SW $\frac{1}{2}$ S |
| 4 | 45 0 0 | NE | NW | SE | SW |
| $4\frac{1}{2}$ | 50 37 30 | NE $\frac{1}{2}$ E | NW $\frac{1}{2}$ W | SE $\frac{1}{2}$ E | SW $\frac{1}{2}$ W |
| 5 | 56 15 0 | NE by E | NW by W | SE by E | SW by W |
| $5\frac{1}{2}$ | 61 52 30 | ENE $\frac{1}{2}$ N | WNW $\frac{1}{2}$ N | ESE $\frac{1}{2}$ S | WSW $\frac{1}{2}$ S |
| 6 | 67 30 0 | ENE | WNW | ESE | WSW |
| $6\frac{1}{2}$ | 73 7 30 | ENE $\frac{1}{2}$ E | WNW $\frac{1}{2}$ W | ESE $\frac{1}{2}$ E | WSW $\frac{1}{2}$ W |
| 7 | 78 45 0 | E by N | W by N | E by S | W by S |
| $7\frac{1}{2}$ | 84 22 30 | E $\frac{1}{2}$ N | W $\frac{1}{2}$ N | E $\frac{1}{2}$ S | W $\frac{1}{2}$ S |
| 8 | 90 0 0 | EAST | WEST | EAST | WEST |

TABLE 4.—LOGARITHMS OF NUMBERS, FROM 1 TO 10,000.*

| N. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | N. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **0** | — | 000000 | 301030 | 477121 | 602060 | 698970 | 778151 | 845098 | 903090 | 954243 | **0** |
| **1** | 000000 | 041393 | 079181 | 113943 | 146128 | 176091 | 204120 | 230449 | 255273 | 278754 | **1** |
| **2** | 301030 | 322219 | 342423 | 361728 | 380211 | 397940 | 414973 | 431364 | 447158 | 462398 | **2** |
| **3** | 477121 | 491362 | 505150 | 518514 | 531479 | 544068 | 556303 | 568202 | 579784 | 591065 | **3** |
| **4** | 602060 | 612784 | 623249 | 633468 | 643453 | 653213 | 662758 | 672098 | 681241 | 690196 | **4** |
| **5** | 698970 | 707570 | 716003 | 724276 | 732394 | 740363 | 748188 | 755875 | 763428 | 770852 | **5** |
| **6** | 778151 | 785330 | 792392 | 799341 | 806180 | 812913 | 819544 | 826075 | 832509 | 838849 | **6** |
| **7** | 845098 | 851258 | 957332 | 863323 | 869232 | 875061 | 880814 | 886491 | 892095 | 897627 | **7** |
| **8** | 903090 | 908485 | 913814 | 919078 | 924279 | 929419 | 934498 | 939519 | 944483 | 949390 | **8** |
| **9** | 954243 | 959041 | 963788 | 968483 | 973128 | 977724 | 982271 | 986772 | 991226 | 995635 | **9** |
| N. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | N. |

| N. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | D. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **100** | 000000 | 000434 | 000868 | 001301 | 001734 | 002166 | 002598 | 003029 | 003461 | 003891 | **432** |
| **101** | 004321 | 004751 | 005181 | 005609 | 006038 | 006466 | 006894 | 007321 | 007748 | 008174 | **428** |
| **102** | 008600 | 009026 | 009451 | 009876 | 010300 | 010724 | 011147 | 011570 | 011993 | 012415 | **424** |
| **103** | 012837 | 013259 | 013680 | 014100 | 014521 | 014940 | 015360 | 015779 | 016197 | 016616 | **419** |
| **104** | 017033 | 017451 | 017868 | 018284 | 018700 | 019116 | 019532 | 019947 | 020361 | 020775 | **415** |
| **105** | 021189 | 021603 | 022016 | 022428 | 022841 | 023252 | 023664 | 024075 | 024486 | 024896 | **411** |
| **106** | 025306 | 025715 | 026125 | 026533 | 026942 | 027350 | 027757 | 028164 | 028571 | 028978 | **408** |
| **107** | 029384 | 029789 | 030195 | 030600 | 031004 | 031408 | 031812 | 032216 | 032619 | 033021 | **404** |
| **108** | 033424 | 033826 | 034227 | 034628 | 035029 | 035430 | 035830 | 036230 | 036629 | 037028 | **400** |
| **109** | 037426 | 037825 | 038223 | 038620 | 039017 | 039414 | 039811 | 040207 | 040602 | 040998 | **396** |
| **110** | 041393 | 041787 | 042182 | 042576 | 042969 | 043362 | 043755 | 044148 | 044540 | 044932 | **393** |
| N. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | D. |

* See Introduction, *ante*, p. 2.

| N. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | D. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **111** | 045323 | 045714 | 046105 | 046495 | 046885 | 047275 | 047664 | 048053 | 048442 | 048830 | **389** |
| **112** | 049218 | 049606 | 049993 | 050380 | 050766 | 051153 | 051538 | 051924 | 052309 | 052694 | **386** |
| **113** | 053078 | 053463 | 053846 | 054230 | 054613 | 054996 | 055378 | 055760 | 056142 | 056524 | **383** |
| **114** | 056905 | 057286 | 057666 | 058046 | 058426 | 058805 | 059185 | 059563 | 059942 | 060320 | **379** |
| **115** | 060698 | 061075 | 061452 | 061829 | 062206 | 062582 | 062958 | 063333 | 063709 | 064083 | **376** |
| **116** | 064458 | 064832 | 065206 | 065580 | 065953 | 066326 | 066699 | 067071 | 067443 | 067815 | **373** |
| **117** | 068186 | 068557 | 068928 | 069298 | 069668 | 070038 | 070407 | 070776 | 071145 | 071514 | **369** |
| **118** | 071882 | 072250 | 072617 | 072985 | 073352 | 073718 | 074085 | 074451 | 074816 | 075182 | **366** |
| **119** | 075547 | 075912 | 076276 | 076640 | 077004 | 077368 | 077731 | 078094 | 078457 | 078819 | **363** |
| **120** | 079181 | 079543 | 079904 | 080266 | 080626 | 080987 | 081347 | 081707 | 082067 | 082426 | **360** |
| **121** | 082785 | 083144 | 083503 | 083861 | 084219 | 084576 | 084934 | 085291 | 085647 | 086004 | **357** |
| **122** | 086360 | 086716 | 087071 | 087426 | 087781 | 088136 | 088490 | 088845 | 089198 | 089552 | **354** |
| **123** | 089905 | 090258 | 090611 | 090963 | 091315 | 091667 | 092018 | 092370 | 092721 | 093071 | **351** |
| **124** | 093422 | 093772 | 094122 | 094471 | 094820 | 095169 | 095518 | 095866 | 096215 | 096562 | **349** |
| **125** | 096910 | 097257 | 097604 | 097951 | 098298 | 098644 | 098990 | 099335 | 099681 | 100026 | **346** |
| **126** | 100371 | 100715 | 101059 | 101403 | 101747 | 102091 | 102434 | 102777 | 103119 | 103462 | **343** |
| **127** | 103804 | 104146 | 104487 | 104828 | 105169 | 105510 | 105851 | 106191 | 106531 | 106871 | **340** |
| **128** | 107210 | 107549 | 107888 | 108227 | 108565 | 108903 | 109241 | 109579 | 109916 | 110253 | **338** |
| **129** | 110590 | 110926 | 111263 | 111599 | 111934 | 112270 | 112605 | 112940 | 113275 | 113609 | **335** |
| **130** | 113943 | 114277 | 114611 | 114944 | 115278 | 115611 | 115943 | 116276 | 116608 | 116940 | **332** |
| **131** | 117271 | 117603 | 117934 | 118265 | 118595 | 118926 | 119256 | 119586 | 119915 | 120245 | **330** |
| **132** | 120574 | 120903 | 121231 | 121560 | 121888 | 122216 | 122544 | 122871 | 123198 | 123525 | **327** |
| **133** | 123852 | 124178 | 124504 | 124830 | 125156 | 125481 | 125806 | 126131 | 126456 | 126781 | **325** |
| **134** | 127105 | 127429 | 127753 | 128076 | 128399 | 128722 | 129045 | 129368 | 129690 | 130012 | **322** |
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| **471** | 673021 | 673113 | 673205 | 673297 | 673390 | 673482 | 673574 | 673666 | 673758 | 673850 | **92** |
| **472** | 673942 | 674034 | 674126 | 674218 | 674310 | 674402 | 674494 | 674586 | 674677 | 674769 | **92** |
| **473** | 674861 | 674953 | 675045 | 675137 | 675228 | 675320 | 675412 | 675503 | 675595 | 675687 | **92** |
| **474** | 675778 | 675870 | 675962 | 676053 | 676145 | 676236 | 676328 | 676419 | 676511 | 676602 | **92** |
| **475** | 676694 | 676785 | 676876 | 676968 | 677059 | 677151 | 677242 | 677333 | 677424 | 677516 | **91** |
| **476** | 677607 | 677698 | 677789 | 677881 | 677972 | 678063 | 678154 | 678245 | 678336 | 678427 | **91** |
| **477** | 678518 | 678609 | 678700 | 678791 | 678882 | 678973 | 679064 | 679155 | 679246 | 679337 | **91** |
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| **480** | 681241 | 681332 | 681422 | 681513 | 681603 | 681693 | 681784 | 681874 | 681964 | 682055 | **90** |
| **481** | 682145 | 682235 | 682326 | 682416 | 682506 | 682596 | 682686 | 682777 | 682867 | 682957 | **90** |
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| **484** | 684845 | 684935 | 685025 | 685114 | 685204 | 685294 | 685383 | 685473 | 685563 | 685652 | **90** |
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| 487 | 687529 | 687618 | 687707 | 687796 | 687886 | 687975 | 688064 | 688153 | 688242 | 688331 | 89 |
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| 490 | 690196 | 690285 | 690373 | 690462 | 690550 | 690639 | 690728 | 690816 | 690905 | 690993 | 89 |
| 491 | 691081 | 691170 | 691258 | 691347 | 691435 | 691524 | 691612 | 691700 | 691789 | 691877 | 88 |
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| 493 | 692847 | 692935 | 693023 | 693111 | 693199 | 693287 | 693375 | 693463 | 693551 | 693639 | 88 |
| 494 | 693727 | 693815 | 693903 | 693991 | 694078 | 694166 | 694254 | 694342 | 694430 | 694517 | 88 |
| 495 | 694605 | 694693 | 694781 | 694868 | 694956 | 695044 | 695131 | 695219 | 695307 | 695394 | 88 |
| 496 | 695482 | 695569 | 695657 | 695744 | 695832 | 695919 | 696007 | 696094 | 696182 | 696269 | 87 |
| 497 | 696356 | 696444 | 696531 | 696618 | 696706 | 696793 | 696880 | 696968 | 697055 | 697142 | 87 |
| 498 | 697229 | 697317 | 697404 | 697491 | 697578 | 697665 | 697752 | 697839 | 697926 | 698014 | 87 |
| 499 | 698101 | 698188 | 698275 | 698362 | 698449 | 698535 | 698622 | 698709 | 698796 | 698883 | 87 |
| 500 | 698970 | 699057 | 699144 | 699231 | 699317 | 699404 | 699491 | 699578 | 690664 | 699751 | 87 |
| 501 | 699838 | 699924 | 700011 | 700098 | 700184 | 700271 | 700358 | 700444 | 700531 | 700617 | 87 |
| 502 | 700704 | 700790 | 700877 | 700963 | 701050 | 701136 | 701222 | 701309 | 701395 | 701482 | 86 |
| 503 | 701568 | 701654 | 701741 | 701827 | 701913 | 701999 | 702086 | 702172 | 702258 | 702344 | 86 |
| 504 | 702431 | 702517 | 702603 | 702689 | 702775 | 702861 | 702947 | 703033 | 703119 | 703205 | 86 |
| 505 | 703291 | 703377 | 703463 | 703549 | 703635 | 703721 | 703807 | 703893 | 703979 | 704065 | 86 |
| 506 | 704151 | 704236 | 704322 | 704408 | 704494 | 704579 | 704665 | 704751 | 704837 | 704922 | 86 |
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| 508 | 705864 | 705949 | 706035 | 706120 | 706206 | 706291 | 706376 | 706462 | 706547 | 706632 | 85 |
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| 510 | 707570 | 707655 | 707740 | 707826 | 707911 | 707996 | 708081 | 708166 | 708251 | 708336 | 85 |
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| **513** | 710117 | 710202 | 710287 | 710371 | 710456 | 710540 | 710625 | 710710 | 710794 | 710879 | **85** |
| **514** | 710963 | 711048 | 711132 | 711217 | 711301 | 711385 | 711470 | 711554 | 711639 | 711723 | **84** |
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| **516** | 712650 | 712734 | 712818 | 712902 | 712986 | 713070 | 713154 | 713238 | 713323 | 713407 | **84** |
| **517** | 713491 | 713575 | 713659 | 713742 | 713826 | 713910 | 713994 | 714078 | 714162 | 714246 | **84** |
| **518** | 714330 | 714414 | 714497 | 714581 | 714665 | 714749 | 714833 | 714916 | 715000 | 715084 | **84** |
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| **520** | 716003 | 716087 | 716170 | 716254 | 716337 | 716421 | 716504 | 716588 | 716671 | 716754 | **83** |
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| **523** | 718502 | 718585 | 718668 | 718751 | 718834 | 718917 | 719000 | 719083 | 719165 | 719248 | **83** |
| **524** | 719331 | 719414 | 719497 | 719580 | 719663 | 719745 | 719828 | 719911 | 719994 | 720077 | **83** |
| **525** | 720159 | 720242 | 720325 | 720407 | 720490 | 720573 | 720655 | 720738 | 720821 | 720903 | **83** |
| **526** | 720986 | 721068 | 721151 | 721233 | 721316 | 721398 | 721481 | 721563 | 721646 | 721728 | **83** |
| **527** | 721811 | 721893 | 721975 | 722058 | 722140 | 722222 | 722305 | 722387 | 722469 | 722552 | **82** |
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| **532** | 725912 | 725993 | 726075 | 726156 | 726238 | 726320 | 726401 | 726483 | 726564 | 726646 | **82** |
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| 537 | 729974 | 730055 | 730136 | 730217 | 730298 | 730378 | 730459 | 730540 | 730621 | 730702 | 81 |
| 538 | 730782 | 730863 | 730944 | 731024 | 731105 | 731186 | 731266 | 731347 | 731428 | 731508 | 81 |
| 539 | 731589 | 731669 | 731750 | 731830 | 731911 | 731991 | 732072 | 732152 | 732233 | 732313 | 81 |
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| 541 | 733197 | 733278 | 733358 | 733438 | 733518 | 733598 | 733679 | 733759 | 733839 | 733919 | 80 |
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| 545 | 736397 | 736476 | 736556 | 736635 | 736715 | 736795 | 736874 | 736954 | 737034 | 737113 | 80 |
| 546 | 737193 | 737272 | 737352 | 737431 | 737511 | 737590 | 737670 | 737749 | 737829 | 737908 | 79 |
| 547 | 737987 | 738067 | 738146 | 738225 | 738305 | 738384 | 738463 | 738543 | 738622 | 738701 | 79 |
| 548 | 738781 | 738860 | 738939 | 739018 | 739097 | 739177 | 739256 | 739335 | 739414 | 739493 | 79 |
| 549 | 739572 | 739651 | 739731 | 739810 | 739889 | 739968 | 740047 | 740126 | 740205 | 740284 | 79 |
| 550 | 740363 | 740442 | 740521 | 740600 | 740678 | 740757 | 740836 | 740915 | 740994 | 741073 | 79 |
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| 552 | 741939 | 742018 | 742096 | 742175 | 742254 | 742332 | 742411 | 742489 | 742568 | 742647 | 79 |
| 553 | 742725 | 742804 | 742882 | 742961 | 743039 | 743118 | 743196 | 743275 | 743353 | 743431 | 78 |
| 554 | 743510 | 743588 | 743667 | 743745 | 743823 | 743902 | 743980 | 744058 | 744136 | 744215 | 78 |
| 555 | 744293 | 744371 | 744449 | 744528 | 744606 | 744684 | 744762 | 744840 | 744919 | 744997 | 78 |
| 556 | 745075 | 745153 | 745231 | 745309 | 745387 | 745465 | 745543 | 745621 | 745699 | 745777 | 78 |
| 557 | 745855 | 745933 | 746011 | 746089 | 746167 | 746245 | 746323 | 746401 | 746479 | 746556 | 78 |
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| 560 | 748188 | 748266 | 748343 | 748421 | 748498 | 748576 | 748653 | 748731 | 748808 | 748885 | 77 |
| N. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | D. |

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|---|---|---|---|---|---|---|---|---|---|---|---|
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| 562 | 749736 | 749814 | 749891 | 749968 | 750045 | 750123 | 750200 | 750277 | 750354 | 750431 | 77 |
| 563 | 750508 | 750586 | 750663 | 750740 | 750817 | 750894 | 750971 | 751048 | 751125 | 751202 | 77 |
| 564 | 751279 | 751356 | 751433 | 751510 | 751587 | 751664 | 751741 | 751818 | 751895 | 751972 | 77 |
| 565 | 752048 | 752125 | 752202 | 752279 | 752356 | 752433 | 752509 | 752586 | 752663 | 752740 | 77 |
| 566 | 752816 | 752893 | 752970 | 753047 | 753123 | 753200 | 753277 | 753353 | 753430 | 753506 | 77 |
| 567 | 753583 | 753660 | 753736 | 753813 | 753889 | 753966 | 754042 | 754119 | 754195 | 754272 | 77 |
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| 569 | 755112 | 755189 | 755265 | 755341 | 755417 | 755494 | 755570 | 755646 | 755722 | 755799 | 76 |
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| 572 | 757396 | 757472 | 757548 | 757624 | 757700 | 757775 | 757851 | 757927 | 758003 | 758079 | 76 |
| 573 | 758155 | 758230 | 758306 | 758382 | 758458 | 758533 | 758609 | 758685 | 758761 | 758836 | 76 |
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| 578 | 761928 | 762003 | 762078 | 762153 | 762228 | 762303 | 762378 | 762453 | 762529 | 762604 | 75 |
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| 582 | 764923 | 764998 | 765072 | 765147 | 765221 | 765296 | 765370 | 765445 | 765520 | 765594 | 75 |
| 583 | 765669 | 765743 | 765818 | 765892 | 765966 | 766041 | 766115 | 766190 | 766264 | 766338 | 74 |
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| 585 | 767156 | 767230 | 767304 | 767379 | 767453 | 767527 | 767601 | 767675 | 767749 | 767823 | 74 |
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| 590 | 770852 | 770926 | 770999 | 771073 | 771146 | 771220 | 771293 | 771367 | 771440 | 771514 | 74 |
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| 592 | 772322 | 772395 | 772468 | 772542 | 772615 | 772688 | 772762 | 772835 | 772908 | 772981 | 73 |
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| 594 | 773786 | 773860 | 773933 | 774006 | 774079 | 774152 | 774225 | 774298 | 774371 | 774444 | 73 |
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| 596 | 775246 | 775319 | 775392 | 775465 | 775538 | 775610 | 775683 | 775756 | 775829 | 775902 | 73 |
| 597 | 775974 | 776047 | 776120 | 776193 | 776265 | 776338 | 776411 | 776483 | 776556 | 776629 | 73 |
| 598 | 776701 | 776774 | 776846 | 776919 | 776992 | 777064 | 777137 | 777209 | 777282 | 777354 | 73 |
| 599 | 777427 | 777499 | 777572 | 777644 | 777717 | 777789 | 777862 | 777934 | 778006 | 778079 | 72 |
| 600 | 778151 | 778224 | 778296 | 778368 | 778441 | 778513 | 778585 | 778658 | 778730 | 778802 | 72 |
| 601 | 778874 | 778947 | 779019 | 779091 | 779163 | 779236 | 779308 | 779380 | 779452 | 779524 | 72 |
| 602 | 779596 | 779669 | 779741 | 779813 | 779885 | 779957 | 780029 | 780101 | 780173 | 780245 | 72 |
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| 607 | 783189 | 783260 | 783332 | 783403 | 783475 | 783546 | 783618 | 783689 | 783761 | 783832 | 71 |
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| N. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | D. |

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| 612 | 786751 | 786822 | 786893 | 786964 | 787035 | 787106 | 787177 | 787248 | 787319 | 787390 | 71 |
| 613 | 787460 | 787531 | 787602 | 787673 | 787744 | 787815 | 787885 | 787956 | 788027 | 788098 | 71 |
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| 615 | 788875 | 788946 | 789016 | 789087 | 789157 | 789228 | 789299 | 789369 | 789440 | 789510 | 71 |
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| 629 | 798651 | 798720 | 798789 | 798858 | 798927 | 798996 | 799065 | 799134 | 799203 | 799272 | 69 |
| 630 | 799341 | 799409 | 799478 | 799547 | 799616 | 799685 | 799754 | 799823 | 799892 | 799961 | 69 |
| 631 | 800029 | 800098 | 800167 | 800236 | 800305 | 800373 | 800442 | 800511 | 800580 | 800648 | 69 |
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| 643 | 808211 | 808279 | 808346 | 808414 | 808481 | 808549 | 808616 | 808684 | 808751 | 808818 | 67 |
| 644 | 808886 | 808953 | 809021 | 809088 | 809156 | 809223 | 809290 | 809358 | 809425 | 809492 | 67 |
| 645 | 809560 | 809627 | 809694 | 809762 | 809829 | 809896 | 809964 | 810031 | 810098 | 810165 | 67 |
| 646 | 810233 | 810300 | 810367 | 810434 | 810501 | 810569 | 810636 | 810703 | 810770 | 810837 | 67 |
| 647 | 810904 | 810971 | 811039 | 811106 | 811173 | 811240 | 811307 | 811374 | 811441 | 811508 | 67 |
| 648 | 811575 | 811642 | 811709 | 811776 | 811843 | 811910 | 811977 | 812044 | 812111 | 812178 | 67 |
| 649 | 812245 | 812312 | 812379 | 812445 | 812512 | 812579 | 812646 | 812713 | 812780 | 812847 | 67 |
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| 654 | 815578 | 815644 | 815711 | 815777 | 815843 | 815910 | 815976 | 816042 | 816109 | 816175 | 66 |
| 655 | 816241 | 816308 | 816374 | 816440 | 816506 | 816573 | 816639 | 816705 | 816771 | 816838 | 66 |
| 656 | 816904 | 816970 | 817036 | 817102 | 817169 | 817235 | 817301 | 817367 | 817433 | 817499 | 66 |
| 657 | 817565 | 817631 | 817698 | 817764 | 817830 | 817896 | 817962 | 818028 | 818094 | 818160 | 66 |
| 658 | 818226 | 818292 | 818358 | 818424 | 818490 | 818556 | 818622 | 818688 | 818754 | 818820 | 66 |
| 659 | 818885 | 818951 | 819017 | 819083 | 819149 | 819215 | 819281 | 819346 | 819412 | 819478 | 66 |
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| **412** | 614897 | 615003 | 615108 | 615213 | 615319 | 615424 | 615529 | 615634 | 615740 | 615845 | **105** |
| **413** | 615950 | 616055 | 616160 | 616265 | 616370 | 616476 | 616581 | 616686 | 616790 | 616895 | **105** |
| **414** | 617000 | 617105 | 617210 | 617315 | 617420 | 617525 | 617629 | 617734 | 617839 | 617943 | **105** |
| **415** | 618048 | 618153 | 618257 | 618362 | 618466 | 618571 | 618676 | 618780 | 618884 | 618989 | **105** |
| **416** | 619093 | 619198 | 619302 | 619406 | 619511 | 619615 | 619719 | 619824 | 619928 | 620032 | **104** |
| **417** | 620136 | 620240 | 620344 | 620448 | 620552 | 620656 | 620760 | 620864 | 620968 | 621072 | **104** |
| **418** | 621176 | 621280 | 621384 | 621488 | 621592 | 621695 | 621799 | 621903 | 622007 | 622110 | **104** |
| **419** | 622214 | 622318 | 622421 | 622525 | 622628 | 622732 | 622835 | 622939 | 623042 | 623146 | **104** |
| **420** | 623249 | 623353 | 623456 | 623559 | 623663 | 623766 | 623869 | 623973 | 624076 | 624179 | **103** |
| **421** | 624282 | 624385 | 624488 | 624591 | 624695 | 624798 | 624901 | 625004 | 625107 | 625210 | **103** |
| **422** | 625312 | 625415 | 625518 | 625621 | 625724 | 625827 | 625929 | 626032 | 626135 | 626238 | **103** |
| **423** | 626340 | 626443 | 626546 | 626648 | 626751 | 626853 | 626956 | 627058 | 627161 | 627263 | **103** |
| **424** | 627366 | 627468 | 627571 | 627673 | 627775 | 627878 | 627980 | 628082 | 628185 | 628287 | **102** |
| **423** | 628389 | 628491 | 628593 | 628695 | 628797 | 628900 | 629002 | 629104 | 629206 | 629308 | **102** |
| **426** | 629410 | 629512 | 629613 | 629715 | 629817 | 629919 | 630021 | 630123 | 630224 | 630326 | **102** |
| **427** | 630428 | 630530 | 630631 | 630733 | 630835 | 630936 | 631038 | 631139 | 631241 | 631342 | **102** |
| **428** | 631444 | 631545 | 631647 | 631748 | 631849 | 631951 | 632052 | 632153 | 632255 | 632356 | **101** |
| **429** | 632457 | 632559 | 632660 | 632761 | 632862 | 632963 | 633064 | 633165 | 633266 | 633367 | **101** |
| **430** | 633468 | 633569 | 633670 | 633771 | 633872 | 633973 | 634074 | 634175 | 634276 | 634376 | **101** |
| **431** | 634477 | 634578 | 634679 | 634779 | 634880 | 634981 | 635081 | 635182 | 635283 | 635383 | **101** |
| **432** | 635484 | 635584 | 635685 | 635785 | 635886 | 635986 | 636087 | 636187 | 636287 | 636388 | **100** |
| **433** | 636488 | 636588 | 636688 | 636789 | 636889 | 636989 | 637089 | 637189 | 637290 | 637390 | **100** |
| **434** | 637490 | 637590 | 637690 | 637790 | 637890 | 637990 | 638090 | 638190 | 638290 | 638389 | **100** |
| **435** | 638489 | 638589 | 638689 | 638789 | 638888 | 638988 | 639088 | 639188 | 639287 | 639387 | **100** |
| N. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | D. |

| N. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | D. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **436** | 639486 | 639586 | 639686 | 639785 | 639885 | 639984 | 640084 | 640183 | 640283 | 640382 | **100** |
| **437** | 640481 | 640581 | 640680 | 640779 | 640879 | 640978 | 641077 | 641177 | 641276 | 641375 | **99** |
| **438** | 641474 | 641573 | 641672 | 641771 | 641871 | 641970 | 642069 | 642168 | 642267 | 642366 | **99** |
| **439** | 642465 | 642563 | 642662 | 642761 | 642860 | 642959 | 643058 | 643156 | 643255 | 643354 | **99** |
| **440** | 643453 | 643551 | 643650 | 643749 | 643847 | 643946 | 644044 | 644143 | 644242 | 644340 | **98** |
| **441** | 644439 | 644537 | 644636 | 644734 | 644832 | 644931 | 645029 | 645127 | 645226 | 645324 | **98** |
| **442** | 645422 | 645521 | 645619 | 645717 | 645815 | 645913 | 646011 | 646110 | 646208 | 646306 | **98** |
| **443** | 646404 | 646502 | 646600 | 646698 | 646796 | 646894 | 646992 | 647089 | 647187 | 647285 | **98** |
| **444** | 647383 | 647481 | 647579 | 647676 | 647774 | 647872 | 647969 | 648067 | 648165 | 648262 | **98** |
| **445** | 648360 | 648458 | 648555 | 648653 | 648750 | 648848 | 648945 | 649043 | 649140 | 649237 | **97** |
| **446** | 649335 | 649432 | 649530 | 649627 | 649724 | 649821 | 649919 | 650016 | 650113 | 650210 | **97** |
| **447** | 650308 | 650405 | 650502 | 650599 | 650696 | 650793 | 650890 | 650987 | 651084 | 651181 | **97** |
| **448** | 651278 | 651375 | 651472 | 651569 | 651666 | 651762 | 651859 | 651956 | 652053 | 652150 | **97** |
| **449** | 652246 | 652343 | 652440 | 652536 | 652633 | 652730 | 652826 | 652923 | 653019 | 653116 | **97** |
| **450** | 653213 | 653309 | 653405 | 653502 | 653598 | 653695 | 653791 | 653888 | 653984 | 654080 | **96** |
| **451** | 654177 | 654273 | 654369 | 654465 | 654562 | 654658 | 654754 | 654850 | 654946 | 655042 | **96** |
| **452** | 655138 | 655235 | 655331 | 655427 | 655523 | 655619 | 655715 | 655810 | 655906 | 656002 | **96** |
| **453** | 656098 | 656194 | 656290 | 656386 | 656482 | 656577 | 656673 | 656769 | 656864 | 656960 | **96** |
| **454** | 657056 | 657152 | 657247 | 657343 | 657438 | 657534 | 657629 | 657725 | 657820 | 657916 | **96** |
| **455** | 658011 | 658107 | 658202 | 658298 | 658393 | 658488 | 658584 | 658679 | 658774 | 658870 | **95** |
| **456** | 658965 | 659060 | 659155 | 659250 | 659346 | 659441 | 659536 | 659631 | 659726 | 659821 | **95** |
| **457** | 659916 | 660011 | 660106 | 660201 | 660296 | 660391 | 660486 | 660581 | 660676 | 660771 | **95** |
| **458** | 660865 | 660960 | 661055 | 661150 | 661245 | 661339 | 661434 | 661529 | 661623 | 661718 | **95** |
| **459** | 661813 | 661907 | 662002 | 662096 | 662191 | 662286 | 662380 | 662475 | 662569 | 662663 | **94** |
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| N. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | D. |

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|---|---|---|---|---|---|---|---|---|---|---|---|
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| 462 | 664642 | 664734 | 664830 | 664924 | 665018 | 665112 | 665206 | 665299 | 665393 | 665487 | 94 |
| 463 | 665581 | 665675 | 665769 | 665862 | 665956 | 666050 | 666143 | 666237 | 666331 | 666424 | 94 |
| 464 | 666518 | 666612 | 666705 | 666799 | 666892 | 666986 | 667079 | 667173 | 667266 | 667360 | 94 |
| 465 | 667453 | 667546 | 667640 | 667733 | 667826 | 667920 | 668013 | 668106 | 668199 | 668293 | 93 |
| 466 | 668386 | 668479 | 668572 | 668665 | 668759 | 668852 | 668945 | 669038 | 669131 | 669224 | 93 |
| 467 | 669317 | 669410 | 669503 | 669596 | 669689 | 669782 | 669875 | 669967 | 670060 | 670153 | 93 |
| 468 | 670246 | 670339 | 670431 | 670524 | 670617 | 670710 | 670802 | 670895 | 670988 | 671080 | 93 |
| 469 | 671173 | 671265 | 671358 | 671451 | 671543 | 671636 | 671728 | 671821 | 671913 | 672005 | 92 |
| 470 | 672098 | 672190 | 672283 | 672375 | 672467 | 672560 | 672652 | 672744 | 672836 | 672929 | 92 |
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| 472 | 673942 | 674034 | 674126 | 674218 | 674310 | 674402 | 674494 | 674586 | 674677 | 674769 | 92 |
| 473 | 674861 | 674953 | 675045 | 675137 | 675228 | 675320 | 675412 | 675503 | 675595 | 675687 | 92 |
| 474 | 675778 | 675870 | 675962 | 676053 | 676145 | 676236 | 676328 | 676419 | 676511 | 676602 | 92 |
| 475 | 676694 | 676785 | 676876 | 676968 | 677059 | 677151 | 677242 | 677333 | 677424 | 677516 | 91 |
| 476 | 677607 | 677698 | 677789 | 677881 | 677972 | 678063 | 678154 | 678245 | 678336 | 678427 | 91 |
| 477 | 678518 | 678609 | 678700 | 678791 | 678882 | 678973 | 679064 | 679155 | 679246 | 679337 | 91 |
| 478 | 679428 | 679519 | 679610 | 679700 | 679791 | 679882 | 679973 | 680063 | 680154 | 680245 | 91 |
| 479 | 680336 | 680426 | 680517 | 680607 | 680698 | 680789 | 680879 | 680970 | 681060 | 681151 | 91 |
| 480 | 681241 | 681332 | 681422 | 681513 | 681603 | 681693 | 681784 | 681874 | 681964 | 682055 | 90 |
| 481 | 682145 | 682235 | 682326 | 682416 | 682506 | 682596 | 682686 | 682777 | 682867 | 682957 | 90 |
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| 487 | 687529 | 687618 | 687707 | 687796 | 687886 | 687975 | 688064 | 688153 | 688242 | 688331 | 89 |
| 488 | 688420 | 688509 | 688598 | 688687 | 688776 | 688865 | 688953 | 689042 | 689131 | 689220 | 89 |
| 489 | 689309 | 689398 | 689486 | 689575 | 689664 | 689753 | 689841 | 689930 | 690019 | 690107 | 89 |
| 490 | 690196 | 690285 | 690373 | 690462 | 690550 | 690639 | 690728 | 690816 | 690905 | 690993 | 89 |
| 491 | 691081 | 691170 | 691258 | 691347 | 691435 | 691524 | 691612 | 691700 | 691789 | 691877 | 88 |
| 492 | 691965 | 692053 | 692142 | 692230 | 692318 | 692406 | 692494 | 692583 | 692671 | 692759 | 88 |
| 493 | 692847 | 692935 | 693023 | 693111 | 693199 | 693287 | 693375 | 693463 | 693551 | 693639 | 88 |
| 494 | 693727 | 693815 | 693903 | 693991 | 694078 | 694166 | 694254 | 694342 | 694430 | 694517 | 88 |
| 495 | 694605 | 694693 | 694781 | 694868 | 694956 | 695044 | 695131 | 695219 | 695307 | 695394 | 88 |
| 496 | 695482 | 695569 | 695657 | 695744 | 695832 | 695919 | 696007 | 696094 | 696182 | 696269 | 87 |
| 497 | 696356 | 696444 | 696531 | 696618 | 696706 | 696793 | 696880 | 696968 | 697055 | 697142 | 87 |
| 498 | 697229 | 697317 | 697404 | 697491 | 697578 | 697665 | 697752 | 697839 | 697926 | 698014 | 87 |
| 499 | 698101 | 698188 | 698275 | 698362 | 698449 | 698535 | 698622 | 698709 | 698796 | 698883 | 87 |
| 500 | 698970 | 699057 | 699144 | 699231 | 699317 | 699404 | 699491 | 699578 | 690664 | 699751 | 87 |
| 501 | 699838 | 699924 | 700011 | 700098 | 700184 | 700271 | 700358 | 700444 | 700531 | 700617 | 87 |
| 502 | 700704 | 700790 | 700877 | 700963 | 701050 | 701136 | 701222 | 701309 | 701395 | 701482 | 86 |
| 503 | 701568 | 701654 | 701741 | 701827 | 701913 | 701999 | 702086 | 702172 | 702258 | 702344 | 86 |
| 504 | 702431 | 702517 | 702603 | 702689 | 702775 | 702861 | 702947 | 703033 | 703119 | 703205 | 86 |
| 505 | 703291 | 703377 | 703463 | 703549 | 703635 | 703721 | 703807 | 703893 | 703979 | 704065 | 86 |
| 506 | 704151 | 704236 | 704322 | 704408 | 704494 | 704579 | 704665 | 704751 | 704837 | 704922 | 86 |
| 507 | 705008 | 705094 | 705179 | 705265 | 705350 | 705436 | 705522 | 705607 | 705693 | 705778 | 86 |
| 508 | 705864 | 705949 | 706035 | 706120 | 706206 | 706291 | 706376 | 706462 | 706547 | 706632 | 85 |
| 509 | 706718 | 706803 | 706888 | 706974 | 707059 | 707144 | 707229 | 707315 | 707400 | 707485 | 85 |
| 510 | 707570 | 707655 | 707740 | 707826 | 707911 | 707996 | 708081 | 708166 | 708251 | 708336 | 85 |
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| **512** | 709270 | 709355 | 709440 | 709524 | 709609 | 709694 | 709779 | 709863 | 709948 | 710033 | **85** |
| **513** | 710117 | 710202 | 710287 | 710371 | 710456 | 710540 | 710625 | 710710 | 710794 | 710879 | **85** |
| **514** | 710963 | 711048 | 711132 | 711217 | 711301 | 711385 | 711470 | 711554 | 711639 | 711723 | **84** |
| **515** | 711807 | 711892 | 711976 | 712060 | 712144 | 712229 | 712313 | 712397 | 712481 | 712566 | **84** |
| **516** | 712650 | 712734 | 712818 | 712902 | 712986 | 713070 | 713154 | 713238 | 713323 | 713407 | **84** |
| **517** | 713491 | 713575 | 713659 | 713742 | 713826 | 713910 | 713994 | 714078 | 714162 | 714246 | **84** |
| **518** | 714330 | 714414 | 714497 | 714581 | 714665 | 714749 | 714833 | 714916 | 715000 | 715084 | **84** |
| **519** | 715167 | 715251 | 715335 | 715418 | 715502 | 715586 | 715669 | 715753 | 715836 | 715920 | **84** |
| **520** | 716003 | 716087 | 716170 | 716254 | 716337 | 716421 | 716504 | 716588 | 716671 | 716754 | **83** |
| **521** | 716838 | 716921 | 717004 | 717088 | 717171 | 717254 | 717338 | 717421 | 717504 | 717587 | **83** |
| **522** | 717671 | 717754 | 717837 | 717920 | 718003 | 718086 | 718169 | 718253 | 718336 | 718419 | **83** |
| **523** | 718502 | 718585 | 718668 | 718751 | 718834 | 718917 | 719000 | 719083 | 719165 | 719248 | **83** |
| **524** | 719331 | 719414 | 719497 | 719580 | 719663 | 719745 | 719828 | 719911 | 719994 | 720077 | **83** |
| **525** | 720159 | 720242 | 720325 | 720407 | 720490 | 720573 | 720655 | 720738 | 720821 | 720903 | **83** |
| **526** | 720986 | 721068 | 721151 | 721233 | 721316 | 721398 | 721481 | 721563 | 721646 | 721728 | **83** |
| **527** | 721811 | 721893 | 721975 | 722058 | 722140 | 722222 | 722305 | 722387 | 722469 | 722552 | **82** |
| **528** | 722634 | 722716 | 722798 | 722881 | 722963 | 723045 | 723127 | 723209 | 723291 | 723374 | **82** |
| **529** | 723456 | 723538 | 723620 | 723702 | 723784 | 723866 | 723948 | 724030 | 724112 | 724194 | **82** |
| **530** | 724276 | 724358 | 724440 | 724522 | 724604 | 724685 | 724767 | 724849 | 724931 | 725013 | **82** |
| **531** | 725095 | 725176 | 725258 | 725340 | 725422 | 725503 | 725585 | 725667 | 725748 | 725830 | **82** |
| **532** | 725912 | 725993 | 726075 | 726156 | 726238 | 726320 | 726401 | 726483 | 726564 | 726646 | **82** |
| **533** | 726727 | 726809 | 726890 | 726972 | 727053 | 727134 | 727216 | 727297 | 727379 | 727460 | **81** |
| **534** | 727541 | 727623 | 727704 | 727785 | 727866 | 727948 | 728029 | 728110 | 728191 | 728273 | **81** |
| **535** | 728354 | 728435 | 728516 | 728597 | 728678 | 728759 | 728841 | 728922 | 729003 | 729084 | **81** |
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| 537 | 729974 | 730055 | 730136 | 730217 | 730298 | 730378 | 730459 | 730540 | 730621 | 730702 | 81 |
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| **838** | 923244 | 923296 | 923348 | 923399 | 923451 | 923503 | 923555 | 923607 | 923658 | 923710 | **52** |
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| **843** | 925828 | 925879 | 925931 | 925982 | 926034 | 926085 | 926137 | 926188 | 926240 | 926291 | **51** |
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| **852** | 930440 | 930491 | 930542 | 930592 | 930643 | 930694 | 930745 | 930796 | 930847 | 930898 | **51** |
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| **860** | 934498 | 934549 | 934599 | 934650 | 934700 | 934751 | 934801 | 934852 | 934902 | 934953 | **50** |
| N. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | D. |

| N. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | D. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **861** | 935003 | 935054 | 935104 | 935154 | 935205 | 935255 | 935306 | 935356 | 935406 | 935457 | **50** |
| **862** | 935507 | 935558 | 935608 | 935658 | 935709 | 935759 | 935809 | 935860 | 935910 | 935960 | **50** |
| **863** | 936011 | 936061 | 936111 | 936162 | 936212 | 936262 | 936313 | 936363 | 936413 | 936463 | **50** |
| **864** | 936514 | 936564 | 936614 | 936665 | 936715 | 936765 | 936815 | 936865 | 936916 | 936966 | **50** |
| **865** | 937016 | 937066 | 937117 | 937167 | 937217 | 937267 | 937317 | 937367 | 937418 | 937468 | **50** |
| **866** | 937518 | 937568 | 937618 | 937668 | 937718 | 937769 | 937819 | 937869 | 937919 | 937969 | **50** |
| **867** | 938019 | 938069 | 938119 | 938169 | 938219 | 938269 | 938320 | 938370 | 938420 | 938470 | **50** |
| **868** | 938520 | 938570 | 938620 | 938670 | 938720 | 938770 | 938820 | 938870 | 938920 | 938970 | **50** |
| **869** | 939020 | 939070 | 939120 | 939170 | 939220 | 939270 | 939320 | 939369 | 939419 | 939469 | **50** |
| **870** | 939519 | 939569 | 939619 | 939669 | 939719 | 939769 | 939819 | 939869 | 939918 | 939968 | **50** |
| **871** | 940018 | 940068 | 940118 | 940168 | 940218 | 940267 | 940317 | 940367 | 940417 | 940467 | **50** |
| **872** | 940516 | 940566 | 940616 | 940666 | 940716 | 940765 | 940815 | 940865 | 940915 | 940964 | **50** |
| **873** | 941014 | 941064 | 941114 | 941163 | 941213 | 941263 | 941313 | 941362 | 941412 | 941462 | **50** |
| **874** | 941511 | 941561 | 941611 | 941660 | 941710 | 941760 | 941809 | 941859 | 941909 | 941958 | **50** |
| **875** | 942008 | 942058 | 942107 | 942157 | 942207 | 942256 | 942306 | 942355 | 942405 | 942455 | **50** |
| **876** | 942504 | 942554 | 942603 | 942653 | 942702 | 942752 | 942801 | 942851 | 942901 | 942950 | **50** |
| **877** | 943000 | 943049 | 943099 | 943148 | 943198 | 943247 | 943297 | 943346 | 943396 | 943445 | **49** |
| **878** | 943495 | 943544 | 943593 | 943643 | 943692 | 943742 | 943791 | 943841 | 943890 | 943939 | **49** |
| **879** | 943989 | 944038 | 944088 | 944137 | 944186 | 944236 | 944285 | 944335 | 944384 | 944433 | **49** |
| **880** | 944483 | 944532 | 944581 | 944631 | 944680 | 944729 | 944779 | 944828 | 944877 | 944927 | **49** |
| **881** | 944976 | 945025 | 945074 | 945124 | 945173 | 945222 | 945272 | 945321 | 945370 | 945419 | **49** |
| **882** | 945469 | 945518 | 945567 | 945616 | 945665 | 945715 | 945764 | 945813 | 945862 | 945912 | **49** |
| **883** | 945961 | 946010 | 946059 | 946108 | 946157 | 946207 | 946256 | 946305 | 946354 | 946403 | **49** |
| **884** | 946452 | 946501 | 946551 | 946600 | 946649 | 946698 | 946747 | 946796 | 946845 | 946894 | **49** |
| **885** | 946943 | 946992 | 947041 | 947090 | 947140 | 947189 | 947238 | 947287 | 947336 | 947385 | **49** |
| N. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | D. |

| N. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | D. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 886 | 947434 | 947483 | 947532 | 947581 | 947630 | 947679 | 947728 | 947777 | 947826 | 947875 | 49 |
| 887 | 947924 | 947973 | 948022 | 948070 | 948119 | 948168 | 948217 | 948266 | 948315 | 948364 | 49 |
| 888 | 948413 | 948462 | 948511 | 948560 | 948609 | 948657 | 948706 | 948755 | 948804 | 948853 | 49 |
| 889 | 948902 | 948951 | 948999 | 949048 | 949097 | 949146 | 949195 | 949244 | 949292 | 949341 | 49 |
| 890 | 949390 | 949439 | 949488 | 949536 | 949585 | 949634 | 949683 | 949731 | 949780 | 949829 | 49 |
| 891 | 949878 | 949926 | 949975 | 950024 | 950073 | 950121 | 950170 | 950219 | 950267 | 950316 | 49 |
| 892 | 950365 | 950414 | 950462 | 950511 | 950560 | 950608 | 950657 | 950706 | 950754 | 950803 | 49 |
| 893 | 950851 | 950900 | 950949 | 950997 | 951046 | 951095 | 951143 | 951192 | 951240 | 951289 | 49 |
| 894 | 951338 | 951386 | 951435 | 951483 | 951532 | 951580 | 951629 | 951677 | 951726 | 951775 | 49 |
| 895 | 951823 | 951872 | 951920 | 951969 | 952017 | 952066 | 952114 | 952163 | 952211 | 952260 | 48 |
| 896 | 952308 | 952356 | 952405 | 952453 | 952502 | 952550 | 952599 | 952647 | 952696 | 952744 | 48 |
| 897 | 952792 | 952841 | 952889 | 952938 | 952986 | 953034 | 953083 | 953131 | 953180 | 953228 | 48 |
| 898 | 953276 | 953325 | 953373 | 953421 | 953470 | 953518 | 953566 | 953615 | 953663 | 953711 | 48 |
| 899 | 953760 | 953808 | 953856 | 953905 | 953953 | 954001 | 954049 | 954098 | 954146 | 954194 | 48 |
| 900 | 954243 | 954291 | 954339 | 954387 | 954435 | 954484 | 954532 | 954580 | 954628 | 954677 | 48 |
| 901 | 954725 | 954773 | 954821 | 954869 | 954918 | 954966 | 955014 | 955062 | 955110 | 955158 | 48 |
| 902 | 955207 | 955255 | 955303 | 955351 | 955399 | 955447 | 955495 | 955543 | 955592 | 955640 | 48 |
| 903 | 955688 | 955736 | 955784 | 955832 | 955880 | 955928 | 955976 | 956024 | 956072 | 956120 | 48 |
| 904 | 956168 | 956216 | 956265 | 956313 | 956361 | 956409 | 956457 | 956505 | 956553 | 956601 | 48 |
| 905 | 956649 | 956697 | 956745 | 956793 | 956840 | 956888 | 956936 | 956984 | 957032 | 957080 | 48 |
| 906 | 957128 | 957176 | 957224 | 957272 | 957320 | 957368 | 957416 | 957464 | 957512 | 957559 | 48 |
| 907 | 957607 | 957655 | 957703 | 957751 | 957799 | 957847 | 957894 | 957942 | 957990 | 958038 | 48 |
| 908 | 958086 | 958134 | 958181 | 958229 | 958277 | 958325 | 958373 | 958421 | 958468 | 958516 | 48 |
| 909 | 958564 | 958612 | 958659 | 958707 | 958755 | 958803 | 958850 | 958898 | 958946 | 958994 | 48 |
| 910 | 959041 | 959089 | 959137 | 959185 | 959232 | 959280 | 959328 | 959375 | 959423 | 959471 | 48 |
| N. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | D. |

| N. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | D. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **911** | 959518 | 959566 | 959614 | 959661 | 959709 | 959757 | 959804 | 959852 | 959900 | 959947 | **48** |
| **912** | 959995 | 960042 | 960090 | 960138 | 960185 | 960233 | 960281 | 960328 | 960376 | 960423 | **48** |
| **913** | 960471 | 960518 | 960566 | 960613 | 960661 | 960709 | 960756 | 960804 | 960851 | 960894 | **48** |
| **914** | 960946 | 960994 | 961041 | 961089 | 961136 | 961184 | 961231 | 961279 | 961326 | 961374 | **47** |
| **915** | 961421 | 961469 | 961516 | 961563 | 961611 | 961658 | 961706 | 961753 | 961801 | 961848 | **47** |
| **916** | 961895 | 961943 | 961990 | 962038 | 962085 | 962132 | 962180 | 962227 | 962275 | 962325 | **47** |
| **917** | 962369 | 962417 | 962464 | 962511 | 962559 | 962606 | 962653 | 962701 | 962748 | 962795 | **47** |
| **918** | 962843 | 962890 | 962937 | 962985 | 963032 | 963079 | 963126 | 963174 | 963221 | 963268 | **47** |
| **919** | 963316 | 963363 | 963410 | 963457 | 963504 | 963552 | 963599 | 963646 | 963693 | 963741 | **47** |
| **920** | 963788 | 963835 | 963882 | 963929 | 963977 | 965024 | 964071 | 964118 | 964165 | 964212 | **47** |
| **921** | 964260 | 964307 | 964354 | 964401 | 964448 | 964495 | 964542 | 964590 | 964637 | 964684 | **47** |
| **922** | 964731 | 964778 | 964825 | 964872 | 964919 | 964966 | 965013 | 965061 | 965108 | 965155 | **47** |
| **923** | 965202 | 965249 | 965296 | 965343 | 965390 | 965437 | 965484 | 965531 | 965578 | 965625 | **47** |
| **924** | 965672 | 965719 | 965766 | 965813 | 965860 | 965907 | 965954 | 966001 | 966048 | 966095 | **47** |
| **925** | 966142 | 966189 | 966236 | 966283 | 966329 | 966376 | 966423 | 966470 | 966517 | 966564 | **47** |
| **926** | 966611 | 966658 | 966705 | 966752 | 966799 | 966845 | 966892 | 966939 | 966986 | 967033 | **47** |
| **927** | 967080 | 967127 | 967173 | 967220 | 967267 | 967314 | 967361 | 967408 | 967454 | 967501 | **47** |
| **928** | 967548 | 967595 | 967642 | 967688 | 967735 | 967782 | 967829 | 967875 | 967922 | 967969 | **47** |
| **229** | 968016 | 968062 | 968109 | 968156 | 968203 | 968249 | 968296 | 968343 | 968390 | 968436 | **47** |
| **930** | 968483 | 968530 | 968576 | 968623 | 968670 | 968716 | 968763 | 968810 | 968856 | 968903 | **47** |
| **931** | 968950 | 968996 | 969043 | 969090 | 969136 | 969183 | 969229 | 969276 | 969323 | 969369 | **47** |
| **932** | 969416 | 969463 | 969509 | 969556 | 969602 | 969649 | 969695 | 969742 | 969789 | 969835 | **47** |
| **933** | 969882 | 969928 | 969975 | 970021 | 970068 | 970114 | 970161 | 970207 | 970254 | 970300 | **47** |
| **934** | 970347 | 970393 | 970440 | 970486 | 970533 | 970579 | 970626 | 970672 | 970719 | 970765 | **46** |
| **935** | 970812 | 970858 | 970904 | 970951 | 970997 | 971044 | 971090 | 971137 | 971183 | 971229 | **46** |
| N. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | D. |

| N. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | D. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **936** | 971276 | 971322 | 971369 | 971415 | 971461 | 971508 | 971554 | 971601 | 971647 | 971693 | **46** |
| **937** | 971740 | 971786 | 971832 | 971879 | 971925 | 971971 | 972018 | 972064 | 972110 | 972157 | **46** |
| **938** | 972203 | 972249 | 972295 | 972342 | 972388 | 972434 | 972481 | 972527 | 972573 | 972619 | **46** |
| **939** | 972666 | 972712 | 972758 | 972804 | 972851 | 972897 | 972943 | 972989 | 973035 | 973082 | **46** |
| **940** | 973128 | 973174 | 973220 | 973266 | 973313 | 973359 | 973405 | 973451 | 973497 | 973543 | **46** |
| **941** | 973590 | 973636 | 973682 | 973728 | 973774 | 973820 | 973866 | 973913 | 973959 | 974005 | **46** |
| **942** | 974051 | 974097 | 974143 | 973189 | 974235 | 974281 | 974327 | 974374 | 974420 | 974466 | **46** |
| **943** | 974512 | 974558 | 974604 | 974650 | 974696 | 974742 | 974798 | 974834 | 974880 | 974926 | **46** |
| **944** | 974972 | 975018 | 975064 | 975110 | 975156 | 975202 | 975248 | 975294 | 975340 | 975386 | **46** |
| **945** | 975432 | 975478 | 975524 | 975570 | 975616 | 975662 | 975707 | 975753 | 975799 | 975845 | **46** |
| **946** | 975891 | 975937 | 975983 | 976029 | 976075 | 976121 | 976167 | 976212 | 976258 | 976304 | **46** |
| **947** | 976350 | 976396 | 976442 | 976488 | 976533 | 976579 | 976625 | 976671 | 976717 | 976763 | **46** |
| **948** | 976808 | 976854 | 976900 | 976946 | 976992 | 977037 | 977083 | 977129 | 977175 | 977220 | **46** |
| **949** | 977266 | 977312 | 977358 | 977403 | 977449 | 977495 | 977541 | 977586 | 977632 | 977678 | **46** |
| **950** | 977724 | 977769 | 977815 | 977861 | 977906 | 977952 | 977998 | 978043 | 978089 | 978135 | **46** |
| **951** | 978181 | 978226 | 978272 | 978317 | 978363 | 978409 | 978454 | 978500 | 978546 | 978591 | **46** |
| **952** | 978637 | 978683 | 978728 | 978774 | 978819 | 978865 | 978911 | 978956 | 979002 | 979047 | **46** |
| **953** | 979093 | 979138 | 979184 | 979230 | 979275 | 979321 | 979366 | 979412 | 979457 | 979503 | **46** |
| **954** | 979548 | 979594 | 979639 | 979685 | 979730 | 979776 | 979821 | 979867 | 979912 | 979958 | **46** |
| **955** | 980003 | 980049 | 980094 | 980140 | 980185 | 980231 | 980276 | 980322 | 980367 | 980412 | **45** |
| **956** | 980458 | 980503 | 980549 | 980594 | 980640 | 980685 | 980730 | 980776 | 980821 | 980867 | **45** |
| **957** | 980912 | 980957 | 981003 | 981048 | 981093 | 981139 | 981184 | 981229 | 981275 | 981320 | **45** |
| **958** | 981366 | 981411 | 981456 | 981501 | 981547 | 981592 | 981637 | 981683 | 981728 | 981773 | **45** |
| **959** | 981819 | 981864 | 981909 | 981954 | 982000 | 982045 | 982090 | 982135 | 982181 | 982226 | **45** |
| **960** | 982271 | 982316 | 982362 | 982407 | 982452 | 982497 | 982543 | 982588 | 982633 | 982678 | **45** |
| N. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | D. |

| N. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | D. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 961 | 982723 | 982769 | 982814 | 982859 | 982904 | 982949 | 982994 | 983040 | 983085 | 983130 | 45 |
| 962 | 983175 | 983220 | 983265 | 983310 | 983356 | 983401 | 983446 | 983491 | 983536 | 983581 | 45 |
| 963 | 983626 | 983671 | 983716 | 983762 | 983807 | 983852 | 983897 | 983942 | 983987 | 984032 | 45 |
| 964 | 984077 | 984122 | 984167 | 984212 | 984257 | 984302 | 984347 | 984392 | 984437 | 984482 | 45 |
| 965 | 984527 | 984572 | 984617 | 984662 | 984707 | 984752 | 984797 | 984842 | 984887 | 984932 | 45 |
| 966 | 984977 | 985022 | 985067 | 985112 | 985157 | 985202 | 985247 | 985292 | 985337 | 985382 | 45 |
| 967 | 985426 | 985471 | 985516 | 985561 | 985606 | 985651 | 985696 | 985741 | 985786 | 985830 | 45 |
| 968 | 985875 | 985920 | 985965 | 986010 | 986055 | 986100 | 986144 | 986189 | 986234 | 986279 | 45 |
| 969 | 986324 | 986369 | 986413 | 986458 | 986503 | 986548 | 986593 | 986637 | 986682 | 986727 | 45 |
| 970 | 986772 | 986817 | 986861 | 986906 | 986951 | 986996 | 987040 | 987085 | 987130 | 987175 | 45 |
| 971 | 987219 | 987264 | 987309 | 987353 | 987398 | 987443 | 987488 | 987532 | 987577 | 987622 | 45 |
| 972 | 987666 | 987711 | 987756 | 987800 | 987845 | 987890 | 987934 | 987979 | 988024 | 988068 | 45 |
| 973 | 988113 | 988157 | 988202 | 988247 | 988291 | 988336 | 988381 | 988425 | 988470 | 988514 | 45 |
| 974 | 988559 | 988604 | 988648 | 988693 | 988737 | 988782 | 988826 | 988871 | 988916 | 988960 | 45 |
| 975 | 989005 | 989049 | 989094 | 989138 | 989183 | 989227 | 989272 | 989316 | 989361 | 989405 | 45 |
| 976 | 989450 | 989494 | 989539 | 989583 | 989628 | 989672 | 989717 | 989761 | 989806 | 989850 | 44 |
| 977 | 989895 | 989939 | 989983 | 990028 | 990072 | 990117 | 990161 | 990206 | 990250 | 990294 | 44 |
| 978 | 990339 | 990383 | 990428 | 990472 | 990516 | 990561 | 990605 | 990650 | 990694 | 990738 | 44 |
| 979 | 990783 | 990827 | 990871 | 990916 | 990960 | 991004 | 991049 | 991093 | 991137 | 991182 | 44 |
| 980 | 991226 | 991270 | 991315 | 991359 | 991403 | 991448 | 991492 | 991536 | 991580 | 991625 | 44 |
| 981 | 991669 | 991713 | 991758 | 991802 | 991846 | 991890 | 991935 | 991979 | 992023 | 992067 | 44 |
| 982 | 992111 | 992156 | 992200 | 992244 | 992288 | 992333 | 992377 | 992421 | 992465 | 992509 | 44 |
| 983 | 992554 | 992598 | 992642 | 992686 | 992730 | 992774 | 992819 | 992863 | 992907 | 992951 | 44 |
| 984 | 992995 | 993039 | 993083 | 993127 | 993172 | 993216 | 993260 | 993304 | 993348 | 993392 | 44 |
| 985 | 993436 | 993480 | 993524 | 993568 | 993613 | 993657 | 993701 | 993745 | 993789 | 993833 | 44 |
| N. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | D. |

| N. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | D. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **986** | 993877 | 993921 | 993965 | 994009 | 994053 | 994097 | 994141 | 994185 | 994229 | 994273 | **44** |
| **987** | 994317 | 994361 | 994405 | 994449 | 994493 | 994537 | 994581 | 994625 | 994669 | 994713 | **44** |
| **988** | 994757 | 994801 | 994845 | 994889 | 994933 | 994977 | 995021 | 995065 | 995108 | 995152 | **44** |
| **989** | 995196 | 995240 | 995284 | 995328 | 995372 | 995416 | 995460 | 995504 | 995547 | 995591 | **44** |
| **990** | 995635 | 995679 | 995723 | 995767 | 995811 | 995854 | 995898 | 995942 | 995986 | 996030 | **44** |
| **991** | 996074 | 996117 | 996161 | 996205 | 996249 | 996293 | 996337 | 996380 | 996424 | 996468 | **44** |
| **992** | 996512 | 996555 | 996599 | 996643 | 996687 | 996731 | 996774 | 996818 | 996862 | 996906 | **44** |
| **993** | 996949 | 996993 | 997037 | 997080 | 997124 | 997168 | 997212 | 997255 | 997299 | 997343 | **44** |
| **994** | 997386 | 997430 | 997474 | 997517 | 997561 | 997605 | 997648 | 997692 | 997736 | 997779 | **44** |
| **995** | 997823 | 997867 | 997910 | 997954 | 997998 | 998041 | 998085 | 998129 | 998172 | 998216 | **44** |
| **996** | 998259 | 998303 | 998347 | 998390 | 998434 | 998477 | 998521 | 998564 | 998608 | 998652 | **44** |
| **997** | 998695 | 998739 | 998782 | 998826 | 998869 | 998913 | 998956 | 999000 | 999043 | 999087 | **44** |
| **998** | 999131 | 999174 | 999218 | 999261 | 999305 | 999348 | 999392 | 999435 | 999479 | 999522 | **44** |
| **999** | 999565 | 999609 | 999652 | 999696 | 999739 | 999783 | 999826 | 999870 | 999913 | 999957 | **43** |
| N. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | D. |

## TABLE 5.—HYPERBOLIC LOGARITHMS OF NUMBERS FROM 1·01 TO 20.*

| No. | Log. | No. | Log. | No. | Log. | No. | Log. |
|---|---|---|---|---|---|---|---|
| **1·01** | ·0099 | **1·42** | ·3507 | **1·83** | ·6043 | **2·24** | ·8065 |
| **1·02** | ·0198 | **1·43** | ·3577 | **1·84** | ·6098 | **2·25** | ·8109 |
| **1·03** | ·0296 | **1·44** | ·3646 | **1·85** | ·6152 | **2·26** | ·8154 |
| **1·04** | ·0392 | **1·45** | ·3716 | **1·86** | ·6206 | **2·27** | ·8198 |
| **1·05** | ·0488 | **1·46** | ·3784 | **1·87** | ·6259 | **2·28** | ·8242 |
| **1·06** | ·0583 | **1·47** | ·3853 | **1·88** | ·6313 | **2·29** | ·8286 |
| **1·07** | ·0677 | **1·48** | ·3920 | **1·89** | ·6366 | **2·30** | ·8329 |
| **1·08** | ·0770 | **1·49** | ·3988 | **1·90** | ·6419 | **2·31** | ·8372 |
| **1·09** | ·0862 | **1·50** | ·4055 | **1·91** | ·6471 | **2·32** | ·8416 |
| **1·10** | ·0953 | **1·51** | ·4121 | **1·92** | ·6523 | **2·33** | ·8458 |
| **1·11** | ·1044 | **1·52** | ·4187 | **1·93** | ·6575 | **2·34** | ·8502 |
| **1·12** | ·1133 | **1·53** | ·4253 | **1·94** | ·6627 | **2·35** | ·8544 |
| **1·13** | ·1222 | **1·54** | ·4318 | **1·95** | ·6678 | **2·36** | ·8587 |
| **1·14** | ·1310 | **1·55** | ·4383 | **1·96** | ·6729 | **2·37** | ·8629 |
| **1·15** | ·1398 | **1·56** | ·4447 | **1·97** | ·6780 | **2·38** | ·8671 |
| **1·16** | ·1484 | **1·57** | ·4511 | **1·98** | ·6831 | **2·39** | ·8713 |
| **1·17** | ·1570 | **1·58** | ·4574 | **1·99** | ·6881 | **2·40** | ·8755 |
| **1·18** | ·1655 | **1·59** | ·4637 | **2·00** | ·6931 | **2·41** | ·8796 |
| **1·19** | ·1740 | **1·60** | ·4700 | **2·01** | ·6981 | **2·42** | ·8838 |
| **1·20** | ·1823 | **1·61** | ·4762 | **2·02** | ·7031 | **2·43** | ·8879 |
| **1·21** | ·1906 | **1·62** | ·4824 | **2·03** | ·7080 | **2·44** | ·8920 |
| **1·22** | ·1988 | **1·63** | ·4886 | **2·04** | ·7129 | **2·45** | ·8961 |
| **1·23** | ·2070 | **1·64** | ·4947 | **2·05** | ·7178 | **2·46** | ·9002 |
| **1·24** | ·2151 | **1·65** | ·5008 | **2·06** | ·7227 | **2·47** | ·9042 |
| **1·25** | ·2231 | **1·66** | ·5068 | **2·07** | ·7275 | **2·48** | ·9083 |
| **1·26** | ·2311 | **1·67** | ·5128 | **2·08** | ·7324 | **2·49** | ·9123 |
| **1·27** | ·2390 | **1·68** | ·5188 | **2·09** | ·7372 | **2·50** | ·9163 |
| **1·28** | ·2469 | **1·69** | ·5247 | **2·10** | ·7419 | **2·51** | ·9203 |
| **1·29** | ·2546 | **1·70** | ·5306 | **2·11** | ·7467 | **2·52** | ·9243 |
| **1·30** | ·2624 | **1·71** | ·5365 | **2·12** | ·7514 | **2·53** | ·9282 |
| **1·31** | ·2700 | **1·72** | ·5423 | **2·13** | ·7561 | **2·54** | ·9322 |
| **1·32** | ·2776 | **1·73** | ·5481 | **2·14** | ·7608 | **2·55** | ·9361 |
| **1·33** | ·2852 | **1·74** | ·5539 | **2·15** | ·7655 | **2·56** | ·9400 |
| **1·34** | ·2927 | **1·75** | ·5596 | **2·16** | ·7701 | **2·57** | ·9439 |
| **1·35** | ·3001 | **1·76** | ·5653 | **2·17** | ·7747 | **2·58** | ·9478 |
| **1·36** | ·3075 | **1·77** | ·5710 | **2·18** | ·7793 | **2·59** | ·9517 |
| **1·37** | ·3148 | **1·78** | ·5766 | **2·19** | ·7839 | **2·60** | ·9555 |
| **1·38** | ·3221 | **1·79** | ·5822 | **2·20** | ·7885 | **2·61** | ·9594 |
| **1·39** | ·3293 | **1·80** | ·5878 | **2·21** | 7930 | **2·62** | ·9632 |
| **1·40** | ·3365 | **1·81** | ·5933 | **2·22** | ·7975 | **2·63** | ·9670 |
| **1·41** | ·3436 | **1·82** | ·5988 | **2·23** | ·8020 | **2·64** | ·9708 |

* See Introduction, *ante*, p. 6.

| No. | Log. | No. | Log. | No. | Log. | No. | Log. |
|---|---|---|---|---|---|---|---|
| 2·65 | ·9746 | 3·08 | 1·1249 | 3·51 | 1·2556 | 3·94 | 1·3712 |
| 2·66 | ·9783 | 3·09 | 1·1282 | 3·52 | 1·2585 | 3·95 | 1·3737 |
| 2·67 | ·9821 | 3·10 | 1·1314 | 3·53 | 1·2613 | 3·96 | 1·3762 |
| 2·68 | ·9858 | 3·11 | 1·1346 | 3·54 | 1·2641 | 3·97 | 1·3788 |
| 2·69 | ·9895 | 3·12 | 1·1378 | 3·55 | 1·2669 | 3·98 | 1·3813 |
| 2·70 | ·9933 | 3·13 | 1·1410 | 3·56 | 1·2698 | 3·99 | 1·3838 |
| 2·71 | ·9969 | 3·14 | 1·1442 | 3·57 | 1·2726 | 4·00 | 1·3863 |
| 2·72 | 1·0006 | 3·15 | 1·1474 | 3·58 | 1·2754 | 4·01 | 1·3888 |
| 2·73 | 1·0043 | 3·16 | 1·1506 | 3·59 | 1·2782 | 4·02 | 1·3913 |
| 2·74 | 1·0080 | 3·17 | 1·1537 | 3·60 | 1·2809 | 4·03 | 1·3938 |
| 2·75 | 1·0116 | 3·18 | 1·1569 | 3·61 | 1·2837 | 4·04 | 1·3962 |
| 2·76 | 1·0152 | 3·19 | 1·1600 | 3·62 | 1·2865 | 4·05 | 1·3987 |
| 2·77 | 1·0188 | 3·20 | 1·1632 | 3·63 | 1·2892 | 4·06 | 1·4012 |
| 2·78 | 1·0225 | 3·21 | 1·1663 | 3·64 | 1·2920 | 4·07 | 1·4036 |
| 2·79 | 1·0260 | 3·22 | 1·1694 | 3·65 | 1·2947 | 4·08 | 1·4061 |
| 2·80 | 1·0296 | 3·23 | 1·1725 | 3·66 | 1·2975 | 4·09 | 1·4085 |
| 2·81 | 1·0332 | 3·24 | 1·1756 | 3·67 | 1·3002 | 4·10 | 1·4110 |
| 2·82 | 1·0367 | 3·25 | 1·1787 | 3·68 | 1·3029 | 4·11 | 1·4134 |
| 2·83 | 1·0403 | 3·26 | 1·1817 | 3·69 | 1·3056 | 4·12 | 1·4159 |
| 2·84 | 1·0438 | 3·27 | 1·1848 | 3·70 | 1·3083 | 4·13 | 1·4183 |
| 2·85 | 1·0473 | 3·28 | 1·1878 | 3·71 | 1·3110 | 4·14 | 1·4207 |
| 2·86 | 1·0508 | 3·29 | 1·1909 | 3·72 | 1·3137 | 4·15 | 1·4231 |
| 2·87 | 1·0543 | 3·30 | 1·1939 | 3·73 | 1·3164 | 4·16 | 1·4255 |
| 2·88 | 1·0578 | 3·31 | 1·1969 | 3·74 | 1·3191 | 4·17 | 1·4279 |
| 2·89 | 1·0613 | 3·32 | 1·1999 | 3·75 | 1·3218 | 4·18 | 1·4303 |
| 2·90 | 1·0647 | 3·33 | 1·2030 | 3·76 | 1·3244 | 4·19 | 1·4327 |
| 2·91 | 1·0682 | 3·34 | 1·2060 | 3·77 | 1·3271 | 4·20 | 1·4351 |
| 2·92 | 1·0716 | 3·35 | 1·2090 | 3·78 | 1·3297 | 4·21 | 1·4375 |
| 2·93 | 1·0750 | 3·36 | 1·2119 | 3·79 | 1·3324 | 4·22 | 1·4398 |
| 2·94 | 1·0784 | 3·37 | 1·2149 | 3·80 | 1·3350 | 4·23 | 1·4422 |
| 2·95 | 1·0818 | 3·38 | 1·2179 | 3·81 | 1·3376 | 4·24 | 1·4446 |
| 2·96 | 1·0852 | 3·39 | 1·2208 | 3·82 | 1·3403 | 4·25 | 1·4469 |
| 2·97 | 1·0886 | 3·40 | 1·2238 | 3·83 | 1·3429 | 4·26 | 1·4493 |
| 2·98 | 1·0919 | 3·41 | 1·2267 | 3·84 | 1·3455 | 4·27 | 1·4516 |
| 2·99 | 1·0953 | 3·42 | 1·2296 | 3·85 | 1·3481 | 4·28 | 1·4540 |
| 3·00 | 1·0986 | 3·43 | 1·2326 | 3·86 | 1·3507 | 4·29 | 1·4563 |
| 3·01 | 1·1019 | 3·44 | 1·2355 | 3·87 | 1·3533 | 4·30 | 1·4586 |
| 3·02 | 1·1053 | 3·45 | 1·2384 | 3·88 | 1·3558 | 4·31 | 1·4609 |
| 3·03 | 1·1086 | 3·46 | 1·2413 | 3·89 | 1·3584 | 4·32 | 1·4633 |
| 3·04 | 1·1119 | 3·47 | 1·2442 | 3·90 | 1·3610 | 4·33 | 1·4656 |
| 3·05 | 1·1151 | 3·48 | 1·2470 | 3·91 | 1·3635 | 4·34 | 1·4679 |
| 3·06 | 1·1184 | 3·49 | 1·2499 | 3·92 | 1·3661 | 4·35 | 1·4702 |
| 3·07 | 1·1217 | 3·50 | 1·2528 | 3·93 | 1·3686 | 4·36 | 1·4725 |

| No. | Log. | No. | Log. | No. | Log. | No. | Log. |
|---|---|---|---|---|---|---|---|
| 4·37 | 1·4748 | 4·80 | 1·5686 | 5·23 | 1·6544 | 5·66 | 1·7334 |
| 4·38 | 1·4770 | 4·81 | 1·5707 | 5·24 | 1·6563 | 5·67 | 1·7352 |
| 4·39 | 1·4793 | 4·82 | 1·5728 | 5·25 | 1·6582 | 5·68 | 1·7370 |
| 4·40 | 1·4816 | 4·83 | 1·5748 | 5·26 | 1·6601 | 5·69 | 1·7387 |
| 4·41 | 1·4839 | 4·84 | 1·5769 | 5·27 | 1·6620 | 5·70 | 1·7405 |
| 4·42 | 1·4861 | 4·85 | 1·5790 | 5·28 | 1·6639 | 5·71 | 1·7422 |
| 4·43 | 1·4884 | 4·86 | 1·5810 | 5·29 | 1·6658 | 5·72 | 1·7440 |
| 4·44 | 1·4907 | 4·87 | 1·5831 | 5·30 | 1·6677 | 5·73 | 1·7457 |
| 4·45 | 1·4929 | 4·88 | 1·5851 | 5·31 | 1·6696 | 5·74 | 1·7475 |
| 4·46 | 1·4951 | 4·89 | 1·5872 | 5·32 | 1·6715 | 5·75 | 1·7492 |
| 4·47 | 1·4974 | 4·90 | 1·5892 | 5·33 | 1·6734 | 5·76 | 1·7509 |
| 4·48 | 1·4996 | 4·91 | 1·5913 | 5·34 | 1·6752 | 5·77 | 1·7527 |
| 4·49 | 1·5019 | 4·92 | 1·5933 | 5·35 | 1·6771 | 5·78 | 1·7544 |
| 4·50 | 1·5041 | 4·93 | 1·5953 | 5·36 | 1·6790 | 5·79 | 1·7561 |
| 4·51 | 1·5063 | 4·94 | 1·5974 | 5·37 | 1·6808 | 5·80 | 1·7579 |
| 4·52 | 1·5085 | 4·95 | 1·5994 | 5·38 | 1·6827 | 5·81 | 1·7596 |
| 4·53 | 1·5107 | 4·96 | 1·6014 | 5·39 | 1·6845 | 5·82 | 1·7613 |
| 4·54 | 1·5129 | 4·97 | 1·6034 | 5·40 | 1·6864 | 5·83 | 1·7630 |
| 4·55 | 1·5151 | 4·98 | 1·6054 | 5·41 | 1·6882 | 5·84 | 1·7647 |
| 4·56 | 1·5173 | 4·99 | 1·6074 | 5·42 | 1·6901 | 5·85 | 1·7664 |
| 4·57 | 1·5195 | 5·00 | 1·6094 | 5·43 | 1·6919 | 5·86 | 1·7681 |
| 4·58 | 1·5217 | 5·01 | 1·6114 | 5·44 | 1·6938 | 5·87 | 1·7699 |
| 4·59 | 1·5239 | 5·02 | 1·6134 | 5·45 | 1·6956 | 5·88 | 1·7716 |
| 4·60 | 1·5261 | 5·03 | 1·6154 | 5·46 | 1·6974 | 5·89 | 1·7733 |
| 4·61 | 1·5282 | 5·04 | 1·6174 | 5·47 | 1·6993 | 5·90 | 1·7750 |
| 4·62 | 1·5304 | 5·05 | 1·6194 | 5·48 | 1·7011 | 5·91 | 1·7766 |
| 4·63 | 1·5326 | 5·06 | 1·6214 | 5·49 | 1·7029 | 5·92 | 1·7783 |
| 4·64 | 1·5347 | 5·07 | 1·6233 | 5·50 | 1·7047 | 5·93 | 1·7800 |
| 4·65 | 1·5369 | 5·08 | 1·6253 | 5·51 | 1·7066 | 5·94 | 1·7817 |
| 4·66 | 1·5390 | 5·09 | 1·6273 | 5·52 | 1·7084 | 5·95 | 1·7834 |
| 4·67 | 1·5412 | 5·10 | 1·6292 | 5·53 | 1·7102 | 5·96 | 1·7851 |
| 4·68 | 1·5433 | 5·11 | 1·6312 | 5·54 | 1·7120 | 5·97 | 1·7867 |
| 4·69 | 1·5454 | 5·12 | 1·6332 | 5·55 | 1·7138 | 5·98 | 1·7884 |
| 4·70 | 1·5476 | 5·13 | 1·6351 | 5·56 | 1·7156 | 5·99 | 1·7901 |
| 4·71 | 1·5497 | 5·14 | 1·6371 | 5·57 | 1·7174 | 6·00 | 1·7918 |
| 4·72 | 1·5518 | 5·15 | 1·6390 | 5·58 | 1·7192 | 6·01 | 1·7934 |
| 4·73 | 1·5539 | 5·16 | 1·6409 | 5·59 | 1·7210 | 6·02 | 1·7951 |
| 4·74 | 1·5560 | 5·17 | 1·6429 | 5·60 | 1·7228 | 6·03 | 1·7967 |
| 4·75 | 1·5581 | 5·18 | 1·6448 | 5·61 | 1·7246 | 6·04 | 1·7984 |
| 4·76 | 1·5602 | 5·19 | 1·6467 | 5·62 | 1·7263 | 6·05 | 1·8001 |
| 4·77 | 1·5623 | 5·20 | 1·6487 | 5·63 | 1·7281 | 6·06 | 1·8017 |
| 4·78 | 1·5644 | 5·21 | 1·6506 | 5·64 | 1·7299 | 6·07 | 1·8034 |
| 4·79 | 1·5665 | 5·22 | 1·6525 | 5·65 | 1·7317 | 6·08 | 1·8050 |

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| **6·09** | 1·8066 | **6·52** | 1·8749 | **6·95** | 1·9387 | **7·38** | 1·9988 |
| **6·10** | 1·8083 | **6·53** | 1·8764 | **6·96** | 1·9402 | **7·39** | 2·0001 |
| **6·11** | 1·8099 | **6·54** | 1·8779 | **6·97** | 1·9416 | **7·40** | 2·0015 |
| **6·12** | 1·8116 | **6·55** | 1·8795 | **6·98** | 1·9430 | **7·41** | 2·0028 |
| **6·13** | 1·8132 | **6·56** | 1·8810 | **6·99** | 1·9445 | **7·42** | 2·0042 |
| **6·14** | 1·8148 | **6·57** | 1·8825 | **7·00** | 1·9459 | **7·43** | 2·0055 |
| **6·15** | 1·8165 | **6·58** | 1·8840 | **7·01** | 1·9473 | **7·44** | 2·0069 |
| **6·16** | 1·8181 | **6·59** | 1·8856 | **7·02** | 1·9488 | **7·45** | 2·0082 |
| **6·17** | 1·8197 | **6·60** | 1·8871 | **7·03** | 1·9502 | **7·46** | 2·0096 |
| **6·18** | 1·8213 | **6·61** | 1·8886 | **7·04** | 1·9516 | **7·47** | 2·0109 |
| **6·19** | 1·8229 | **6·62** | 1·8901 | **7·05** | 1·9530 | **7·48** | 2·0122 |
| **6·20** | 1·8245 | **6·63** | 1·8916 | **7·06** | 1·9544 | **7·49** | 2·0136 |
| **6·21** | 1·8262 | **6·64** | 1·8931 | **7·07** | 1·9559 | **7·50** | 2·0149 |
| **6·22** | 1·8278 | **6·65** | 1·8946 | **7·08** | 1·9573 | **7·51** | 2·0162 |
| **6·23** | 1·8294 | **6·66** | 1·8961 | **7·09** | 1·9587 | **7·52** | 2·0176 |
| **6·24** | 1·8310 | **6·67** | 1·8976 | **7·10** | 1·9601 | **7·53** | 2·0189 |
| **6·25** | 1·8326 | **6·68** | 1·8991 | **7·11** | 1·9615 | **7·54** | 2·0202 |
| **6·26** | 1·8342 | **6·69** | 1·9006 | **7·12** | 1·9629 | **7·55** | 2·0215 |
| **6·27** | 1·8358 | **6·70** | 1·9021 | **7·13** | 1·9643 | **7·56** | 2·0229 |
| **6·28** | 1·8374 | **6·71** | 1·9036 | **7·14** | 1·9657 | **7·57** | 2·0242 |
| **6·29** | 1·8390 | **6·72** | 1·9051 | **7·15** | 1·9671 | **7·58** | 2·0255 |
| **6·30** | 1·8405 | **6·73** | 1·9066 | **7·16** | 1·9685 | **7·59** | 2·0268 |
| **6·31** | 1·8421 | **6·74** | 1·9081 | **7·17** | 1·9699 | **7·60** | 2·0281 |
| **6·32** | 1·8437 | **6·75** | 1·9095 | **7·18** | 1·9713 | **7·61** | 2·0295 |
| **6·33** | 1·8453 | **6·76** | 1·9110 | **7·19** | 1·9727 | **7·62** | 2·0308 |
| **6·34** | 1·8469 | **6·77** | 1·9125 | **7·20** | 1·9741 | **7·63** | 2·0321 |
| **6·35** | 1·8485 | **6·78** | 1·9140 | **7·21** | 1·9755 | **7·64** | 2·0334 |
| **6·36** | 1·8500 | **6·79** | 1·9155 | **7·22** | 1·9769 | **7·65** | 2·0347 |
| **6·37** | 1·8516 | **6·80** | 1·9169 | **7·23** | 1·9782 | **7·66** | 2·0360 |
| **6·38** | 1·8532 | **6·81** | 1·9184 | **7·24** | 1·9796 | **7·67** | 2·0373 |
| **6·39** | 1·8547 | **6·82** | 1·9199 | **7·25** | 1·9810 | **7·68** | 2·0386 |
| **6·40** | 1·8563 | **6·83** | 1·9213 | **7·26** | 1·9824 | **7·69** | 2·0399 |
| **6·41** | 1·8579 | **6·84** | 1·9228 | **7·27** | 1·9838 | **7·70** | 2·0412 |
| **6·42** | 1·8594 | **6·85** | 1·9242 | **7·28** | 1·9851 | **7·71** | 2·0425 |
| **6·43** | 1·8610 | **6·86** | 1·9257 | **7·29** | 1·9865 | **7·72** | 2·0438 |
| **6·44** | 1·8625 | **6·87** | 1·9272 | **7·30** | 1·9879 | **7·73** | 2·0451 |
| **6·45** | 1·8641 | **6·88** | 1·9286 | **7·31** | 1·9892 | **7·74** | 2·0464 |
| **6·46** | 1·8656 | **6·89** | 1·9301 | **7·32** | 1·9906 | **7·75** | 2·0477 |
| **6·47** | 1·8672 | **6·90** | 1·9315 | **7·33** | 1·9920 | **7·76** | 2·0490 |
| **6·48** | 1·8687 | **6·91** | 1·9330 | **7·34** | 1·9933 | **7·77** | 2·0503 |
| **6·49** | 1·8703 | **6·92** | 1·9344 | **7·35** | 1·9947 | **7·78** | 2·0516 |
| **6·50** | 1·8718 | **6·93** | 1·9359 | **7·36** | 1·9961 | **7·79** | 2·0528 |
| **6·51** | 1·8733 | **6·94** | 1·9373 | **7·37** | 1·9974 | **7·80** | 2·0541 |

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| **7·81** | 2·0554 | **8·24** | 2·1090 | **8·67** | 2·1599 | **9·10** | 2·2083 |
| **7·82** | 2·0567 | **8·25** | 2·1102 | **8·68** | 2·1610 | **9·11** | 2·2094 |
| **7·83** | 2·0580 | **8·26** | 2·1114 | **8·69** | 2·1622 | **9·12** | 2·2105 |
| **7·84** | 2·0592 | **8·27** | 2·1126 | **8·70** | 2·1633 | **9·13** | 2·2116 |
| **7·85** | 2·0605 | **8·28** | 2·1138 | **8·71** | 2·1645 | **9·14** | 2·2127 |
| **7·86** | 2·0618 | **8·29** | 2·1150 | **8·72** | 2·1656 | **9·15** | 2·2138 |
| **7·87** | 2·0631 | **8·30** | 2·1163 | **8·73** | 2·1668 | **9·16** | 2·2148 |
| **7·88** | 2·0643 | **8·31** | 2·1175 | **8·74** | 2·1679 | **9·17** | 2·2159 |
| **7·89** | 2·0656 | **8·32** | 2·1187 | **8·75** | 2·1691 | **9·18** | 2·2170 |
| **7·90** | 2·0669 | **8·33** | 2·1199 | **8·76** | 2·1702 | **9·19** | 2·2181 |
| **7·91** | 2·0681 | **8·34** | 2·1211 | **8·77** | 2·1713 | **9·20** | 2·2192 |
| **7·92** | 2·0694 | **8·35** | 2·1223 | **8·78** | 2·1725 | **9·21** | 2·2203 |
| **7·93** | 2·0707 | **8·36** | 2·1235 | **8·79** | 2·1736 | **9·22** | 2·2214 |
| **7·94** | 2·0719 | **8·37** | 2·1247 | **8·80** | 2·1748 | **9·23** | 2·2225 |
| **7·95** | 2·0732 | **8·38** | 2·1258 | **8·81** | 2·1759 | **9·24** | 2·2235 |
| **7·96** | 2·0744 | **8·39** | 2·1270 | **8·82** | 2·1770 | **9·25** | 2·2246 |
| **7·97** | 2·0757 | **8·40** | 2·1282 | **8·83** | 2·1782 | **9·26** | 2·2257 |
| **7·98** | 2·0769 | **8·41** | 2·1294 | **8·84** | 2·1793 | **9·27** | 2·2268 |
| **7·99** | 2·0782 | **8·42** | 2·1306 | **8·85** | 2·1804 | **9·28** | 2·2279 |
| **8·00** | 2·0794 | **8·43** | 2·1318 | **8·86** | 2·1815 | **9·29** | 2·2289 |
| **8·01** | 2·0807 | **8·44** | 2·1330 | **8·87** | 2·1827 | **9·30** | 2·2300 |
| **8·02** | 2·0819 | **8·45** | 2·1342 | **8·88** | 2·1838 | **9·31** | 2·2311 |
| **8·03** | 2·0832 | **8·46** | 2·1353 | **8·89** | 2·1849 | **9·32** | 2·2322 |
| **8·04** | 2·0844 | **8·47** | 2·1365 | **8·90** | 2·1861 | **9·33** | 2·2332 |
| **8·05** | 2·0857 | **8·48** | 2·1377 | **8·91** | 2·1872 | **9·34** | 2·2343 |
| **8·06** | 2·0869 | **8·49** | 2·1389 | **8·92** | 2·1883 | **9·35** | 2·2354 |
| **8·07** | 2·0882 | **8·50** | 2·1401 | **8·93** | 2·1894 | **9·36** | 2·2364 |
| **8·08** | 2·0894 | **8·51** | 2·1412 | **8·94** | 2·1905 | **9·37** | 2·2375 |
| **8·09** | 2·0906 | **8·52** | 2·1424 | **8·95** | 2·1917 | **9·38** | 2·2386 |
| **8·10** | 2·0919 | **8·53** | 2·1436 | **8·96** | 2·1928 | **9·39** | 2·2396 |
| **8·11** | 2·0931 | **8·54** | 2·1448 | **8·97** | 2·1939 | **9·40** | 2·2407 |
| **8·12** | 2·0943 | **8·55** | 2·1459 | **8·98** | 2·1950 | **9·41** | 2·2418 |
| **8·13** | 2·0956 | **8·56** | 2·1471 | **9·99** | 2·1961 | **9·42** | 2·2428 |
| **8·14** | 2·0968 | **8·57** | 2·1483 | **9·00** | 2·1972 | **9·43** | 2·2439 |
| **8·15** | 2·0980 | **8·58** | 2·1494 | **9·01** | 2·1983 | **9·44** | 2·2450 |
| **8·16** | 2·0992 | **8·59** | 2·1506 | **9·02** | 2·1994 | **9·45** | 2·2460 |
| **8·17** | 2·1005 | **8·60** | 2·1518 | **9·03** | 2·2006 | **9·46** | 2·2471 |
| **8·18** | 2·1017 | **8·61** | 2·1529 | **9·04** | 2·2017 | **9·47** | 2·2481 |
| **8·19** | 2·1029 | **8·62** | 2·1541 | **9·05** | 2·2028 | **9·48** | 2·2492 |
| **8·20** | 2·1041 | **8·63** | 2·1552 | **9·06** | 2·2039 | **9·49** | 2·2502 |
| **8·21** | 2·1054 | **8·64** | 2·1564 | **9·07** | 2·2050 | **9·50** | 2·2513 |
| **8·22** | 2·1066 | **8·65** | 2·1576 | **9·08** | 2·2061 | **9·51** | 2·2523 |
| **8·23** | 2·1078 | **8·66** | 2·1587 | **9·09** | 2·2072 | **9·52** | 2·2534 |

| No. | Log. | No. | Log. | No. | Log. | No. | Log. |
|---|---|---|---|---|---|---|---|
| **9·53** | 2·2544 | **9·73** | 2·2752 | **9·93** | 2·2956 | **13·25** | 2·5840 |
| **9·54** | 2·2555 | **9·74** | 2·2762 | **9·94** | 2·2966 | **13·50** | 2·6027 |
| **9·55** | 2·2565 | **9·75** | 2·2773 | **9·95** | 2·2976 | **13·75** | 2·6211 |
| **9·56** | 2·2576 | **9·76** | 2·2783 | **9·96** | 2·2986 | **14·00** | 2·6391 |
| **9·57** | 2·2586 | **9·77** | 2·2793 | **9·97** | 2·2996 | **14·25** | 2·6567 |
| **9·58** | 2·2597 | **9·78** | 2·2803 | **9·98** | 2·3006 | **14·50** | 2·6740 |
| **9·59** | 2·2607 | **9·79** | 2·2814 | **9·99** | 2·3016 | **14·75** | 2·6913 |
| **9·60** | 2·2618 | **9·80** | 2·2824 | **10·00** | 2·3026 | **15·00** | 2·7081 |
| **9·61** | 2·2628 | **9·81** | 2·2834 | **10·25** | 2·3279 | **15·50** | 2·7408 |
| **9·62** | 2·2638 | **9·82** | 2·2844 | **10·50** | 2·3513 | **16·00** | 2·7726 |
| **9·63** | 2·2649 | **9·83** | 2·2854 | **10·75** | 2·3749 | **16·50** | 2·8034 |
| **9·64** | 2·2659 | **9·84** | 2·2865 | **11·00** | 2·3979 | **17·00** | 2·8332 |
| **9·65** | 2·2670 | **9·85** | 2·2875 | **11·25** | 2·4201 | **17·50** | 2·8621 |
| **9·66** | 2·2680 | **9·86** | 2·2885 | **11·50** | 2·4430 | **18·00** | 2·8904 |
| **9·67** | 2·2690 | **9·87** | 2·2895 | **11·75** | 2·4636 | **18·50** | 2·9173 |
| **9·68** | 2·2701 | **9·88** | 2·2905 | **12·00** | 2·4849 | **19·00** | 2·9444 |
| **9·69** | 2·2711 | **9·89** | 2·2915 | **12·25** | 2·5052 | **19·50** | 2·9703 |
| **9·70** | 2·2721 | **9·90** | 2·2925 | **12·50** | 2·5262 | **20·00** | 2·9957 |
| **9·71** | 2·2732 | **9·91** | 2·2935 | **12·75** | 2·5455 | | |
| **9·72** | 2·2742 | **9·92** | 2·2946 | **13·00** | 2·5649 | | |

## TABLE 6.—SINES AND COSINES OF ANGLES FROM 0° TO 90°.*

(RADIUS = 1.)

| Sines of Angles. | Cosines of Angles. | Values. | Sines of Angles. | Cosines of Angles. | Values. |
|---|---|---|---|---|---|
| ° | ° | | ° | ° | |
| 0 | 90 | ·00000 | 5·5 | 84·5 | ·09585 |
| 0·5 | 89·5 | ·00873 | 6 | 84 | ·10453 |
| 1 | 89 | ·01745 | 6·5 | 83·5 | ·11320 |
| 1·5 | 88·5 | ·02618 | 7 | 83 | ·12187 |
| 2 | 88 | ·03490 | 7·5 | 82·5 | ·13053 |
| 2·5 | 87·5 | ·04362 | 8 | 82 | ·13917 |
| 3 | 87 | ·05234 | 8·5 | 81·5 | ·14781 |
| 3·5 | 86·5 | ·06105 | 9 | 81 | ·15643 |
| 4 | 86 | ·06976 | 9·5 | 80·5 | ·16505 |
| 4·5 | 85·5 | ·07846 | 10 | 80 | ·17365 |
| 5 | 85 | ·08716 | 10·5 | 79·5 | ·18224 |

* See Introduction, *ante*, p. 6.

| Sines of Angles. | Cosines of Angles. | Values. | Sines of Angles. | Cosines of Angles. | Values. |
|---|---|---|---|---|---|
| ° | ° | | ° | ° | |
| 11 | 79 | ·19081 | 31·5 | 58·5 | ·52250 |
| 11·5 | 78·5 | ·19937 | 32 | 58 | ·52992 |
| 12 | 78 | ·20791 | 32·5 | 57·5 | ·53730 |
| 12·5 | 77·5 | ·21644 | 33 | 57 | ·54464 |
| 13 | 77 | ·22495 | 33·5 | 56·5 | ·55194 |
| 13·5 | 76·5 | ·23344 | 34 | 56 | ·55919 |
| 14 | 76 | ·24192 | 34·5 | 55·5 | ·56641 |
| 14·5 | 75·5 | ·25038 | 35 | 55 | ·57358 |
| 15 | 75 | ·25882 | 35·5 | 54·5 | ·58070 |
| 15·5 | 74·5 | ·26724 | 36 | 54 | ·58778 |
| 16 | 74 | ·27564 | 36·5 | 53·5 | ·59482 |
| 16·5 | 73·5 | ·28401 | 37 | 53 | ·60181 |
| 17 | 73 | ·29237 | 37·5 | 52·5 | ·60876 |
| 17·5 | 72·5 | ·30071 | 38 | 52 | ·61566 |
| 18 | 72 | ·30902 | 38·5 | 51·5 | ·62251 |
| 18·5 | 71·5 | ·31730 | 39 | 51 | ·62932 |
| 19 | 71 | ·32557 | 39·5 | 50·5 | ·63608 |
| 19·5 | 70·5 | ·33381 | 40 | 50 | ·64279 |
| 20 | 70 | ·34202 | 40·5 | 49·5 | ·64945 |
| 20·5 | 69·5 | ·35021 | 41 | 49 | ·65606 |
| 21 | 69 | ·35837 | 41·5 | 48·5 | ·66262 |
| 21·5 | 68·5 | ·36650 | 42 | 48 | ·66913 |
| 22 | 68 | ·37461 | 42·5 | 47·5 | ·67559 |
| 22·5 | 67·5 | ·38268 | 43 | 47 | ·68200 |
| 23 | 67 | ·39073 | 43·5 | 46·5 | ·68835 |
| 23·5 | 66·5 | ·39875 | 44 | 46 | ·69466 |
| 24 | 66 | ·40674 | 44·5 | 45·5 | ·70091 |
| 24·5 | 65·5 | ·41469 | 45 | 45 | ·70711 |
| 25 | 65 | ·42262 | 45·5 | 44·5 | ·71325 |
| 25·5 | 64·5 | ·43051 | 46 | 44 | ·71934 |
| 26 | 64 | ·43837 | 46·5 | 43·5 | ·72537 |
| 26·5 | 63·5 | ·44620 | 47 | 43 | ·73135 |
| 27 | 63 | ·45399 | 47·5 | 42·5 | ·73728 |
| 27·5 | 62·5 | ·46175 | 48 | 42 | ·74314 |
| 28 | 62 | ·46947 | 48·5 | 41·5 | ·74896 |
| 28·5 | 61·5 | ·47716 | 49 | 41 | ·75471 |
| 29 | 61 | ·48481 | 49·5 | 40·5 | ·76041 |
| 29·5 | 60·5 | ·49242 | 50 | 40 | ·76604 |
| 30 | 60 | ·50000 | 50·5 | 39·5 | ·77162 |
| 30·5 | 59·5 | ·50754 | 51 | 39 | ·77715 |
| 31 | 59 | ·51504 | 51·5 | 38·5 | ·78261 |

| Sines of Angles. | Cosines of Angles. | Values. | Sines of Angles. | Cosines of Angles. | Values. |
|---|---|---|---|---|---|
| ° | ° | | ° | ° | |
| 52 | 38 | ·78801 | 71·5 | 18·5 | ·94832 |
| 52·5 | 37·5 | ·79335 | 72 | 18 | ·95106 |
| 53 | 37 | ·79864 | 72·5 | 17·5 | ·95372 |
| 53·5 | 36·5 | ·80386 | 73 | 17 | ·95630 |
| 54 | 36 | ·80902 | 73·5 | 16·5 | ·95882 |
| 54·5 | 35·5 | ·81412 | 74 | 16 | ·96126 |
| 55 | 35 | ·81915 | 74·5 | 15·5 | ·96363 |
| 55·5 | 34·5 | ·82413 | 75 | 15 | ·96593 |
| 56 | 34 | ·82904 | 75·5 | 14·5 | ·96815 |
| 56·5 | 33·5 | ·83389 | 76 | 14 | ·97030 |
| 57 | 33 | ·83867 | 76·5 | 13·5 | ·97237 |
| 57·5 | 32·5 | ·84339 | 77 | 13 | ·97437 |
| 58 | 32 | ·84805 | 77·5 | 12·5 | ·97630 |
| 58·5 | 31·5 | ·85264 | 78 | 12 | ·97815 |
| 59 | 31 | ·85717 | 78·5 | 11·5 | ·97992 |
| 59·5 | 30·5 | ·86163 | 79 | 11 | ·98163 |
| 60 | 30 | ·86602 | 79·5 | 10·5 | ·98325 |
| 60·5 | 29·5 | ·87036 | 80 | 10 | ·98481 |
| 61 | 29 | ·87462 | 80·5 | 9·5 | ·98629 |
| 61·5 | 28·5 | ·87882 | 81 | 9 | ·98769 |
| 62 | 28 | ·88295 | 81·5 | 8·5 | ·98902 |
| 62·5 | 27·5 | ·88701 | 82 | 8 | ·99027 |
| 63 | 27 | ·89101 | 82·5 | 7·5 | ·99144 |
| 63·5 | 26·5 | ·89493 | 83 | 7 | ·99255 |
| 64 | 26 | ·89879 | 83·5 | 6·5 | ·99357 |
| 64·5 | 25·5 | ·90258 | 84 | 6 | ·99452 |
| 65 | 25 | ·90631 | 84·5 | 5·5 | ·99540 |
| 65·5 | 24·5 | ·90996 | 85 | 5 | ·99619 |
| 66 | 24 | ·91354 | 85·5 | 4·5 | ·99692 |
| 66·5 | 23·5 | ·91706 | 86 | 4 | ·99756 |
| 67 | 23 | ·92050 | 86·5 | 3·5 | ·99813 |
| 67·5 | 22·5 | ·92388 | 87 | 3 | ·99863 |
| 68 | 22 | ·92718 | 87·5 | 2·5 | ·99905 |
| 68·5 | 21·5 | ·93042 | 88 | 2 | ·99939 |
| 69 | 21 | ·93358 | 88·5 | 1·5 | ·99966 |
| 69·5 | 20·5 | ·93667 | 89 | 1 | ·99985 |
| 70 | 20 | ·93969 | 89·5 | 0·5 | ·99996 |
| 70·5 | 19·5 | ·94264 | 90 | 0 | 1·00000 |
| 71 | 19 | ·94552 | | | |

## Table 7.—Tangents and Cotangents of Angles from 0° to 90°.*

(Radius = 1.)

| Tangents of Angles. | Cotangents of Angles. | Values. | Tangents of Angles. | Cotangents of Angles. | Values. |
|---|---|---|---|---|---|
| ° | ° | | ° | ° | |
| 0 | 90 | ·00000 | 18·5 | 71·5 | ·33459 |
| 0·5 | 89·5 | ·00873 | 19 | 71 | ·34433 |
| 1 | 89 | ·01745 | 19·5 | 70·5 | ·35412 |
| 1·5 | 88·5 | ·02619 | 20 | 70 | ·36397 |
| 2 | 88 | ·03492 | 20·5 | 69·5 | ·37388 |
| 2·5 | 87·5 | ·04366 | 21 | 69 | ·38386 |
| 3 | 87 | ·05241 | 21·5 | 68·5 | ·39391 |
| 3·5 | 86·5 | ·06116 | 22 | 68 | ·40403 |
| 4 | 86 | ·06993 | 22·5 | 67·5 | ·41421 |
| 4·5 | 85·5 | ·07870 | 23 | 67 | ·42447 |
| 5 | 85 | ·08749 | 23·5 | 66·5 | ·43481 |
| 5·5 | 84·5 | ·09629 | 24 | 66 | ·44523 |
| 6 | 84 | ·10510 | 24·5 | 65·5 | ·45573 |
| 6·5 | 83·5 | ·11394 | 25 | 65 | ·46631 |
| 7 | 83 | ·12278 | 25·5 | 64·5 | ·47698 |
| 7·5 | 82·5 | ·13165 | 26 | 64 | ·48773 |
| 8 | 82 | ·14054 | 26·5 | 63·5 | ·49858 |
| 8·5 | 81·5 | ·14945 | 27 | 63 | ·50952 |
| 9 | 81 | ·15838 | 27·5 | 62·5 | ·52057 |
| 9·5 | 80·5 | ·16734 | 28 | 62 | ·53171 |
| 10 | 80 | ·17633 | 28·5 | 61·5 | ·54296 |
| 10·5 | 79·5 | ·18534 | 29 | 61 | ·55431 |
| 11 | 79 | ·19438 | 29·5 | 60·5 | ·56577 |
| 11·5 | 78·5 | ·20345 | 30 | 60 | ·57735 |
| 12 | 78 | ·21256 | 30·5 | 59·5 | ·58904 |
| 12·5 | 77·5 | ·22169 | 31 | 59 | ·60086 |
| 13 | 77 | ·23087 | 31·5 | 58·5 | ·61280 |
| 13·5 | 76·5 | ·24008 | 32 | 58 | ·62487 |
| 14 | 76 | ·24933 | 32·5 | 57·5 | ·63708 |
| 14·5 | 75·5 | ·25862 | 33 | 57 | ·64941 |
| 15 | 75 | ·26795 | 33·5 | 56·5 | ·66189 |
| 15·5 | 74·5 | ·27732 | 34 | 56 | ·67451 |
| 16 | 74 | ·28674 | 34·5 | 55·5 | ·68728 |
| 16·5 | 73·5 | ·29621 | 35 | 55 | ·70021 |
| 17 | 73 | ·30573 | 35·5 | 54·5 | ·71329 |
| 17·5 | 72·5 | ·31530 | 36 | 54 | ·72654 |
| 18 | 72 | ·32492 | 36·5 | 53·5 | ·73996 |

* See Introduction, *ante*, p. 6.

| Tangents of Angles. | Cotangents of Angles. | Values. | Tangents of Angles. | Cotangents of Angles. | Values. |
|---|---|---|---|---|---|
| ° | ° | | ° | ° | |
| 37 | 53 | ·75355 | 57·5 | 32·5 | 1·56969 |
| 37·5 | 52·5 | ·76763 | 58 | 32 | 1·60033 |
| 38 | 52 | ·78129 | 58·5 | 31·5 | 1·63185 |
| 38·5 | 51·5 | ·79544 | 59 | 31 | 1·66428 |
| 39 | 51 | ·80978 | 59·5 | 30·5 | 1·69766 |
| 39·5 | 50·5 | ·82434 | 60 | 30 | 1·73205 |
| 40 | 50 | ·83910 | 60·5 | 29·5 | 1·76749 |
| 40·5 | 49·5 | ·85408 | 61 | 29 | 1·80405 |
| 41 | 49 | ·86929 | 61·5 | 28·5 | 1·84174 |
| 41·5 | 48·5 | ·88472 | 62 | 28 | 1·88073 |
| 42 | 48 | ·90040 | 62·5 | 27·5 | 1·92098 |
| 42·5 | 47·5 | ·91633 | 63 | 27 | 1·96261 |
| 43 | 47 | ·93251 | 63·5 | 26·5 | 2·00569 |
| 43·5 | 46·5 | ·94896 | 64 | 26 | 2·05030 |
| 44 | 46 | ·96569 | 64·5 | 25·5 | 2·09654 |
| 44·5 | 45·5 | ·98270 | 65 | 25 | 2·14451 |
| 45 | 45 | 1·00000 | 65·5 | 24·5 | 2·19430 |
| 45·5 | 44·5 | 1·01761 | 66 | 24 | 2·24604 |
| 46 | 44 | 1·03553 | 66·5 | 23·5 | 2·29984 |
| 46·5 | 43·5 | 1·05378 | 67 | 23 | 2·35585 |
| 47 | 43 | 1·07237 | 67·5 | 22·5 | 2·41421 |
| 47·5 | 42·5 | 1·09131 | 68 | 22 | 2·47509 |
| 48 | 42 | 1·11061 | 68·5 | 21·5 | 2·53865 |
| 48·5 | 41·5 | 1·13029 | 69 | 21 | 2·60509 |
| 49 | 41 | 1·15037 | 69·5 | 20·5 | 2·67462 |
| 49·5 | 40·5 | 1·17085 | 70 | 20 | 2·74748 |
| 50 | 40 | 1·19175 | 70·5 | 19·5 | 2·82391 |
| 50·5 | 39·5 | 1·21310 | 71 | 19 | 2·90421 |
| 51 | 39 | 1·23490 | 71·5 | 18·5 | 2·98868 |
| 51·5 | 38·5 | 1·25717 | 72 | 18 | 3·07768 |
| 52 | 38 | 1·27994 | 72·5 | 17·5 | 3·17159 |
| 52·5 | 37·5 | 1·30323 | 73 | 17 | 3·27085 |
| 53 | 37 | 1·32704 | 73·5 | 16·5 | 3·37594 |
| 53·5 | 36·5 | 1·35142 | 74 | 16 | 3·48741 |
| 54 | 36 | 1·37638 | 74·5 | 15·5 | 3·60588 |
| 54·5 | 35·5 | 1·40195 | 75 | 15 | 3·73205 |
| 55 | 35 | 1·42815 | 75·5 | 14·5 | 3·86671 |
| 55·5 | 34·5 | 1·45501 | 76 | 14 | 4·01078 |
| 56 | 34 | 1·48256 | 76·5 | 13·5 | 4·16530 |
| 56·5 | 33·5 | 1·51084 | 77 | 13 | 4·33148 |
| 57 | 33 | 1·53986 | 77·5 | 12·5 | 4·51071 |

| Tangents of Angles. | Cotangents of Angles. | Values. | Tangents of Angles. | Cotangents of Angles. | Values. |
|---|---|---|---|---|---|
| ° | ° | | ° | ° | |
| 78 | 12 | 4·70463 | 84·5 | 5·5 | 10·38540 |
| 78·5 | 11·5 | 4·91516 | 85 | 5 | 11·43005 |
| 79 | 11 | 5·14455 | 85·5 | 4·5 | 12·70620 |
| 79·5 | 10·5 | 5·39552 | 86 | 4 | 14·30067 |
| 80 | 10 | 5·67128 | 86·5 | 3·5 | 16·34985 |
| 80·5 | 9·5 | 5·97576 | 87 | 3 | 19·08114 |
| 81 | 9 | 6·31375 | 87·5 | 2·5 | 22·90377 |
| 81·5 | 8·5 | 6·69116 | 88 | 2 | 28·63625 |
| 82 | 8 | 7·11537 | 88·5 | 1·5 | 38·18846 |
| 82·5 | 7·5 | 7·59575 | 89 | 1 | 57·28996 |
| 83 | 7 | 8·14435 | 89·5 | 0·5 | 114·58865 |
| 83·5 | 6·5 | 8·77689 | 90 | 0 | infinite. |
| 84 | 6 | 9·51436 | | | |

## TABLE 8.—LENGTHS OF CIRCULAR ARCS FROM 1° TO 180°.*
(RADIUS = 1.)

| Deg. | Length. | Deg. | Length. | Deg. | Length. | Deg. | Length. |
|---|---|---|---|---|---|---|---|
| **1** | ·0175 | **20** | ·3491 | **39** | ·6807 | **58** | 1·0123 |
| **2** | ·0349 | **21** | ·3665 | **40** | ·6981 | **59** | 1·0297 |
| **3** | ·0524 | **22** | ·3840 | **41** | ·7156 | **60** | 1·0472 |
| **4** | ·0698 | **23** | ·4014 | **42** | ·7330 | **61** | 1·0647 |
| **5** | ·0873 | **24** | ·4189 | **43** | ·7505 | **62** | 1·0821 |
| **6** | ·1047 | **25** | ·4363 | **44** | ·7679 | **63** | 1·0996 |
| **7** | ·1222 | **26** | ·4538 | **45** | ·7854 | **64** | 1·1170 |
| **8** | ·1396 | **27** | ·4712 | **46** | ·8029 | **65** | 1·1345 |
| **9** | ·1571 | **28** | ·4887 | **47** | ·8203 | **66** | 1·1519 |
| **10** | ·1745 | **29** | ·5061 | **48** | ·8378 | **67** | 1·1694 |
| **11** | ·1920 | **30** | ·5236 | **49** | ·8552 | **68** | 1·1868 |
| **12** | ·2094 | **31** | ·5411 | **50** | ·8727 | **69** | 1·2043 |
| **13** | ·2269 | **32** | ·5585 | **51** | ·8901 | **70** | 1·2217 |
| **14** | ·2443 | **33** | ·5760 | **52** | ·9076 | **71** | 1·2392 |
| **15** | ·2618 | **34** | ·5934 | **53** | ·9250 | **72** | 1·2566 |
| **16** | ·2793 | **35** | ·6109 | **54** | ·9425 | **73** | 1·2741 |
| **17** | ·2967 | **36** | ·6283 | **55** | ·9599 | **74** | 1·2915 |
| **18** | ·3142 | **37** | ·6458 | **56** | ·9774 | **75** | 1·3090 |
| **19** | ·3316 | **38** | ·6632 | **57** | ·9948 | **76** | 1·3265 |

* See Introduction, *ante*, p. 7.

| Deg. | Length. | Deg. | Length. | Deg. | Length. | Deg. | Length. |
|---|---|---|---|---|---|---|---|
| **77** | 1·3439 | **103** | 1·7977 | **129** | 2·2515 | **155** | 2·7053 |
| **78** | 1·3613 | **104** | 1·8151 | **130** | 2·2690 | **156** | 2·7227 |
| **79** | 1·3788 | **105** | 1·8326 | **131** | 2·2864 | **157** | 2·7402 |
| **80** | 1·3963 | **106** | 1·8500 | **132** | 2·3038 | **158** | 2·7576 |
| **81** | 1·4137 | **107** | 1·8675 | **133** | 2·3213 | **159** | 2·7751 |
| **82** | 1·4312 | **108** | 1·8850 | **134** | 2·3387 | **160** | 2·7925 |
| **83** | 1·4486 | **109** | 1·9024 | **135** | 2·3562 | **161** | 2·8100 |
| **84** | 1·4661 | **110** | 1·9199 | **136** | 2·3736 | **162** | 2·8274 |
| **85** | 1·4835 | **111** | 1·9373 | **137** | 2·3911 | **163** | 2·8449 |
| **86** | 1·5010 | **112** | 1·9548 | **138** | 2·4086 | **164** | 2·8623 |
| **87** | 1·5184 | **113** | 1·9722 | **139** | 2·4260 | **165** | 2·8798 |
| **88** | 1·5359 | **114** | 1·9897 | **140** | 2·4435 | **166** | 2·8912 |
| **89** | 1·5533 | **115** | 2·0071 | **141** | 2·4609 | **167** | 2·9147 |
| **90** | 1·5708 | **116** | 2·0246 | **142** | 2·4784 | **168** | 2·9321 |
| **91** | 1·5882 | **117** | 2·0420 | **143** | 2·4958 | **169** | 2·9496 |
| **92** | 1·6057 | **118** | 2·0595 | **144** | 2·5133 | **170** | 2·9671 |
| **93** | 1·6232 | **119** | 2·0769 | **145** | 2·5307 | **171** | 2·9845 |
| **94** | 1·6406 | **120** | 2·0944 | **146** | 2·5482 | **172** | 3·0020 |
| **95** | 1·6581 | **121** | 2·1118 | **147** | 2·5656 | **173** | 3·0194 |
| **96** | 1·6755 | **122** | 2·1293 | **148** | 2·5831 | **174** | 3·0369 |
| **97** | 1·6930 | **123** | 2·1468 | **149** | 2·6005 | **175** | 3·0543 |
| **98** | 1·7104 | **124** | 2·1642 | **150** | 2·6180 | **176** | 3·0718 |
| **99** | 1·7279 | **125** | 2·1817 | **151** | 2·6354 | **177** | 3·0892 |
| **100** | 1·7453 | **126** | 2·1991 | **152** | 2·6529 | **178** | 3·1067 |
| **101** | 1·7628 | **127** | 2·2166 | **153** | 2·6704 | **179** | 3·1241 |
| **102** | 1·7802 | **128** | 2·2304 | **154** | 2·6878 | **180** | 3·1416 |

TABLE 9.—LENGTHS OF CIRCULAR ARCS, UP TO A SEMI-CIRCLE.*

(CHORD = 1.)

| Height. | Length. | Height. | Length. | Height. | Length. | Height. | Length. |
|---|---|---|---|---|---|---|---|
| **·001** | 1·00002 | **·009** | 1·00022 | **·017** | 1·00078 | **·025** | 1·00167 |
| **·002** | 1·00002 | **·010** | 1·00027 | **·018** | 1·00081 | **·026** | 1·00182 |
| **·003** | 1·00003 | **·011** | 1·00032 | **·019** | 1·00097 | **·027** | 1·00196 |
| **·004** | 1·00004 | **·012** | 1·00038 | **·020** | 1·00107 | **·028** | 1·00210 |
| **·005** | 1·00007 | **·013** | 1·00045 | **·021** | 1·00117 | **·029** | 1·00225 |
| **·006** | 1·00010 | **·014** | 1·00053 | **·022** | 1·00128 | **·030** | 1·00240 |
| **·007** | 1·00013 | **·015** | 1·00061 | **·023** | 1·00140 | **·031** | 1·00256 |
| **·008** | 1·00017 | **·016** | 1·00069 | **·024** | 1·00153 | **·032** | 1·00272 |

* See Introduction, *ante*, p. 7.

| Height. | Length. | Height. | Length. | Height. | Length. | Height. | Length. |
|---|---|---|---|---|---|---|---|
| ·033 | 1·00289 | ·076 | 1·01533 | ·119 | 1·03734 | ·162 | 1·06858 |
| ·034 | 1·00307 | ·077 | 1·01573 | ·120 | 1·03797 | ·163 | 1·06941 |
| ·035 | 1·00327 | ·078 | 1·01614 | ·121 | 1·03860 | ·164 | 1·07025 |
| ·036 | 1·00345 | ·079 | 1·01656 | ·122 | 1·03923 | ·165 | 1·07109 |
| ·037 | 1·00364 | ·080 | 1·01698 | ·123 | 1·03987 | ·166 | 1·07194 |
| ·038 | 1·00384 | ·081 | 1·01741 | ·124 | 1·04051 | ·167 | 1·07279 |
| ·039 | 1·00405 | ·082 | 1·01784 | ·125 | 1·04116 | ·168 | 1·07365 |
| ·040 | 1·00426 | ·083 | 1·01828 | ·126 | 1·04181 | ·169 | 1·07451 |
| ·041 | 1·00447 | ·084 | 1·01872 | ·127 | 1·04247 | ·170 | 1·07537 |
| ·042 | 1·00469 | ·085 | 1·01916 | ·128 | 1·04313 | ·171 | 1·07624 |
| ·043 | 1·00492 | ·086 | 1·01961 | ·129 | 1·04380 | ·172 | 1·07711 |
| ·044 | 1·00515 | ·087 | 1·02006 | ·130 | 1·04447 | ·173 | 1·07799 |
| ·045 | 1·00539 | ·088 | 1·02052 | ·131 | 1·04515 | ·174 | 1·07888 |
| ·046 | 1·00563 | ·089 | 1·02098 | ·132 | 1·04584 | ·175 | 1·07977 |
| ·047 | 1·00587 | ·090 | 1·02146 | ·133 | 1·04652 | ·176 | 1·08066 |
| ·048 | 1·00612 | ·091 | 1·02192 | ·134 | 1·04722 | ·177 | 1·08156 |
| ·049 | 1·00638 | ·092 | 1·02240 | ·135 | 1·04792 | ·178 | 1·08246 |
| ·050 | 1·00665 | ·093 | 1·02289 | ·136 | 1·04862 | ·179 | 1·08337 |
| ·051 | 1·00692 | ·094 | 1·02339 | ·137 | 1·04932 | ·180 | 1·08428 |
| ·052 | 1·00720 | ·095 | 1·02389 | ·138 | 1·05003 | ·181 | 1·08519 |
| ·053 | 1·00748 | ·096 | 1·02440 | ·139 | 1·05075 | ·182 | 1·08611 |
| ·054 | 1·00776 | ·097 | 1·02491 | ·140 | 1·05147 | ·183 | 1·08704 |
| ·055 | 1·00805 | ·098 | 1·02542 | ·141 | 1·05220 | ·184 | 1·08797 |
| ·056 | 1·00834 | ·099 | 1·02593 | ·142 | 1·05293 | ·185 | 1·08890 |
| ·057 | 1·00864 | ·100 | 1·02646 | ·143 | 1·05367 | ·186 | 1·08984 |
| ·058 | 1·00895 | ·101 | 1·02698 | ·144 | 1·05441 | ·187 | 1·09079 |
| ·059 | 1·00926 | ·102 | 1·02752 | ·145 | 1·05516 | ·188 | 1·09174 |
| ·060 | 1·00957 | ·103 | 1·02806 | ·146 | 1·05591 | ·189 | 1·09269 |
| ·061 | 1·00989 | ·104 | 1·02860 | ·147 | 1·05667 | ·190 | 1·09365 |
| ·062 | 1·01021 | ·105 | 1·02914 | ·148 | 1·05743 | ·191 | 1·09461 |
| ·063 | 1·01054 | ·106 | 1·02970 | ·149 | 1·05819 | ·192 | 1·09557 |
| ·064 | 1·01088 | ·107 | 1·03026 | ·150 | 1·05896 | ·193 | 1·09654 |
| ·065 | 1·01123 | ·108 | 1·03082 | ·151 | 1·05973 | ·194 | 1·09752 |
| ·066 | 1·01158 | ·109 | 1·03139 | ·152 | 1·06051 | ·195 | 1·09850 |
| ·067 | 1·01193 | ·110 | 1·03196 | ·153 | 1·06130 | ·196 | 1·09949 |
| ·068 | 1·01229 | ·111 | 1·03254 | ·154 | 1·06209 | ·197 | 1·10048 |
| ·069 | 1·01264 | ·112 | 1·03312 | ·155 | 1·06288 | ·198 | 1·10147 |
| ·070 | 1·01302 | ·113 | 1·03371 | ·156 | 1·06368 | ·199 | 1·10247 |
| ·071 | 1·01338 | ·114 | 1·03430 | ·157 | 1·06449 | ·200 | 1·10347 |
| ·072 | 1·01376 | ·115 | 1·03490 | ·158 | 1·06530 | ·201 | 1·10447 |
| ·073 | 1·01414 | ·116 | 1·03551 | ·159 | 1·06611 | ·202 | 1·10548 |
| ·074 | 1·01453 | ·117 | 1·03611 | ·160 | 1·06693 | ·203 | 1·10650 |
| ·075 | 1·01493 | ·118 | 1·03672 | ·161 | 1·06775 | ·204 | 1·10752 |

| Height. | Length. | Height. | Length. | Height. | Length. | Height. | Length. |
|---|---|---|---|---|---|---|---|
| ·205 | 1·10855 | ·248 | 1·15670 | ·291 | 1·21239 | ·334 | 1·27502 |
| ·206 | 1·10958 | ·249 | 1·15791 | ·292 | 1·21377 | ·335 | 1·27656 |
| ·207 | 1·11062 | ·250 | 1·15912 | ·293 | 1·21515 | ·336 | 1·27810 |
| ·208 | 1·11165 | ·251 | 1·16034 | ·294 | 1·21654 | ·337 | 1·27864 |
| ·209 | 1·11269 | ·252 | 1·16156 | ·295 | 1·21794 | ·338 | 1·28118 |
| ·210 | 1·11374 | ·253 | 1·16279 | ·296 | 1·21933 | ·339 | 1·28273 |
| ·211 | 1·11479 | ·254 | 1·16402 | ·297 | 1·22073 | ·340 | 1·28428 |
| ·212 | 1·11584 | ·255 | 1·16526 | ·298 | 1·22213 | ·341 | 1·28583 |
| ·213 | 1·11690 | ·256 | 1·16650 | ·299 | 1·22354 | ·342 | 1·28739 |
| ·214 | 1·11796 | ·257 | 1·16774 | ·300 | 1·22495 | ·343 | 1·28895 |
| ·215 | 1·11904 | ·258 | 1·16899 | ·301 | 1·22636 | ·344 | 1·29052 |
| ·216 | 1·12011 | ·259 | 1·17024 | ·302 | 1·22778 | ·345 | 1·29209 |
| ·217 | 1·12118 | ·260 | 1·17150 | ·303 | 1·22920 | ·346 | 1·29366 |
| ·218 | 1·12225 | ·261 | 1·17276 | ·304 | 1·23063 | ·347 | 1·29523 |
| ·219 | 1·12334 | ·262 | 1·17403 | ·305 | 1·23206 | ·348 | 1·29681 |
| ·220 | 1·12444 | ·263 | 1·17530 | ·306 | 1·23349 | ·349 | 1·29838 |
| ·221 | 1·12554 | ·264 | 1·17657 | ·307 | 1·23492 | ·350 | 1·29997 |
| ·222 | 1·12664 | ·265 | 1·17784 | ·308 | 1·23636 | ·351 | 1·30156 |
| ·223 | 1·12774 | ·266 | 1·17912 | ·309 | 1·23780 | ·352 | 1·30315 |
| ·224 | 1·12885 | ·267 | 1·18040 | ·310 | 1·23926 | ·353 | 1·30474 |
| ·225 | 1·12997 | ·268 | 1·18169 | ·311 | 1·24070 | ·354 | 1·30634 |
| ·226 | 1·13108 | ·269 | 1·18299 | ·312 | 1·24216 | ·355 | 1·30794 |
| ·227 | 1·13219 | ·270 | 1·18429 | ·313 | 1·24361 | ·356 | 1·30954 |
| ·228 | 1·13331 | ·271 | 1·18559 | ·314 | 1·24507 | ·357 | 1·31115 |
| ·229 | 1·13444 | ·272 | 1·18689 | ·315 | 1·24654 | ·358 | 1·31276 |
| ·230 | 1·13557 | ·273 | 1·18820 | ·316 | 1·24801 | ·359 | 1·31437 |
| ·231 | 1·13671 | ·274 | 1·18951 | ·317 | 1·24948 | ·360 | 1·31599 |
| ·232 | 1·13785 | ·275 | 1·19082 | ·318 | 1·25095 | ·361 | 1·31761 |
| ·233 | 1·13900 | ·276 | 1·19214 | ·319 | 1·25243 | ·362 | 1·31923 |
| ·234 | 1·14015 | ·277 | 1·19346 | ·320 | 1·25391 | ·363 | 1·32086 |
| ·235 | 1·14131 | ·278 | 1·19479 | ·321 | 1·25540 | ·364 | 1·32249 |
| ·236 | 1·14247 | ·279 | 1·19612 | ·322 | 1·25689 | ·365 | 1·32413 |
| ·237 | 1·14363 | ·280 | 1·19746 | ·323 | 1·25838 | ·366 | 1·32577 |
| ·238 | 1·14480 | ·281 | 1·19880 | ·324 | 1·25988 | ·367 | 1·32741 |
| ·239 | 1·14597 | ·282 | 1·20014 | ·325 | 1·26138 | ·368 | 1·32905 |
| ·240 | 1·14714 | ·283 | 1·20149 | ·326 | 1·26288 | ·339 | 1·33069 |
| ·241 | 1·14832 | ·284 | 1·20284 | ·327 | 1·26437 | ·370 | 1·33234 |
| ·242 | 1·14951 | ·285 | 1·20419 | ·328 | 1·26588 | ·371 | 1·33399 |
| ·243 | 1·15070 | ·286 | 1·20555 | ·329 | 1·26740 | ·372 | 1·33564 |
| ·244 | 1·15189 | ·287 | 1·20691 | ·330 | 1·26892 | ·373 | 1·33730 |
| ·245 | 1·15308 | ·288 | 1·20827 | ·331 | 1·27044 | ·374 | 1·33896 |
| ·246 | 1·15428 | ·289 | 1·20964 | ·332 | 1·27196 | ·375 | 1·34063 |
| ·247 | 1·15549 | ·290 | 1·21202 | ·333 | 1·27349 | ·376 | 1·34229 |

| Height. | Length. | Height | Length. | Height. | Length. | Height. | Length. |
|---|---|---|---|---|---|---|---|
| ·377 | 1·34396 | ·408 | 1·39724 | ·439 | 1·45327 | ·470 | 1·51185 |
| ·378 | 1·34563 | ·409 | 1·39900 | ·440 | 1·45512 | ·471 | 1·51378 |
| ·379 | 1·34731 | ·410 | 1·40077 | ·441 | 1·45697 | ·472 | 1·51571 |
| ·380 | 1·34899 | ·411 | 1·40254 | ·442 | 1·45883 | ·473 | 1·51764 |
| ·381 | 1·35068 | ·412 | 1·40432 | ·443 | 1·46069 | ·474 | 1·51958 |
| ·382 | 1·35237 | ·413 | 1·40610 | ·444 | 1·46255 | ·475 | 1·52152 |
| ·383 | 1·35406 | ·414 | 1·40788 | ·445 | 1·46441 | ·476 | 1·52346 |
| ·384 | 1·35575 | ·415 | 1·40966 | ·446 | 1·46628 | ·477 | 1·52541 |
| ·385 | 1·35744 | ·416 | 1·41145 | ·447 | 1·46815 | ·478 | 1·52736 |
| ·386 | 1·35914 | ·417 | 1·41324 | ·448 | 1·47002 | ·479 | 1·52931 |
| ·387 | 1·36084 | ·418 | 1·41503 | ·449 | 1·47189 | ·480 | 1·53126 |
| ·388 | 1·36254 | ·419 | 1·41682 | ·450 | 1·47377 | ·481 | 1·53322 |
| ·389 | 1·36425 | ·420 | 1·41861 | ·451 | 1·47565 | ·482 | 1·53518 |
| ·390 | 1·36596 | ·421 | 1·42041 | ·452 | 1·47753 | ·483 | 1·53714 |
| ·391 | 1·36767 | ·422 | 1·42221 | ·453 | 1·47942 | ·484 | 1·53910 |
| ·392 | 1·36939 | ·423 | 1·42402 | ·454 | 1·48131 | ·485 | 1·54106 |
| ·393 | 1·37111 | ·424 | 1·42583 | ·455 | 1·48320 | ·486 | 1·54302 |
| ·394 | 1·37283 | ·425 | 1·42764 | ·456 | 1·48509 | ·487 | 1·54499 |
| ·395 | 1·37455 | ·426 | 1·42945 | ·457 | 1·48699 | ·488 | 1·54696 |
| ·396 | 1·37628 | ·427 | 1·43127 | ·458 | 1·48889 | ·489 | 1·54893 |
| ·397 | 1·37801 | ·428 | 1·43309 | ·459 | 1·49079 | ·490 | 1·55091 |
| ·398 | 1·37974 | ·429 | 1·43491 | ·460 | 1·49269 | ·491 | 1·55289 |
| ·399 | 1·38148 | ·430 | 1·43673 | ·461 | 1·49460 | ·492 | 1·55487 |
| ·400 | 1·38322 | ·431 | 1·43856 | ·462 | 1·49651 | ·493 | 1·55685 |
| ·401 | 1·38496 | ·432 | 1·44039 | ·463 | 1·49842 | ·494 | 1·55854 |
| ·402 | 1·38671 | ·433 | 1·44222 | ·464 | 1·50033 | ·495 | 1·56083 |
| ·403 | 1·38846 | ·434 | 1·44405 | ·465 | 1·50224 | ·496 | 1·56282 |
| ·404 | 1·39021 | ·435 | 1·44589 | ·466 | 1·50416 | ·497 | 1·56481 |
| ·405 | 1·39196 | ·436 | 1·44773 | ·467 | 1·50608 | ·498 | 1·56681 |
| ·406 | 1·39372 | ·437 | 1·44957 | ·468 | 1·50800 | ·499 | 1·56881 |
| ·407 | 1·39548 | ·438 | 1·45142 | ·469 | 1·50992 | ·500 | 1·57080 |

## TABLE 10.—AREAS OF CIRCULAR SEGMENTS, UP TO A SEMICIRCLE.*

(DIAMETER OF CIRCLE = 1.)

| Height. | Area. | Height. | Area. | Height. | Area. | Height. | Area. |
|---|---|---|---|---|---|---|---|
| ·001 | ·000042 | ·005 | ·000471 | ·009 | ·001135 | ·013 | ·00197 |
| ·002 | ·000119 | ·006 | ·000619 | ·010 | ·00133 | ·014 | ·00220 |
| ·003 | ·000219 | ·007 | ·000779 | ·011 | ·00153 | ·015 | ·00244 |
| ·004 | ·000337 | ·008 | ·000952 | ·012 | ·00175 | ·016 | ·00268 |

* See Introduction, *ante*, p. 7.

| Height. | Area. | Height. | Area. | Height. | Area. | Height. | Area. |
|---|---|---|---|---|---|---|---|
| ·017 | ·00294 | ·060 | ·01924 | ·103 | ·04269 | ·146 | ·07103 |
| ·018 | ·00320 | ·061 | ·01972 | ·104 | ·04330 | ·147 | ·07174 |
| ·019 | ·00347 | ·062 | ·02020 | ·105 | ·04391 | ·148 | ·07245 |
| ·020 | ·00375 | ·063 | ·02068 | ·106 | ·04452 | ·149 | ·07316 |
| ·021 | ·00403 | ·064 | ·02117 | ·107 | ·04514 | ·150 | ·07387 |
| ·022 | ·00432 | ·065 | ·02166 | ·108 | ·04576 | ·151 | ·07459 |
| ·023 | ·00461 | ·066 | ·02215 | ·109 | ·04638 | ·152 | ·07530 |
| ·024 | ·00492 | ·067 | ·02265 | ·110 | ·04701 | ·153 | ·07603 |
| ·025 | ·00523 | ·068 | ·02315 | ·111 | ·04763 | ·154 | ·07675 |
| ·026 | ·00555 | ·069 | ·02366 | ·112 | ·04826 | ·155 | ·07747 |
| ·027 | ·00587 | ·070 | ·02417 | ·113 | ·04889 | ·156 | ·07819 |
| ·028 | ·00619 | ·071 | ·02468 | ·114 | ·04953 | ·157 | ·07892 |
| ·029 | ·00653 | ·072 | ·02520 | ·115 | ·05016 | ·158 | ·07965 |
| ·030 | ·00687 | ·073 | ·02571 | ·116 | ·05080 | ·159 | ·08038 |
| ·031 | ·00721 | ·074 | ·02624 | ·117 | ·05145 | ·160 | ·08111 |
| ·032 | ·00756 | ·075 | ·02676 | ·118 | ·05209 | ·161 | ·08185 |
| ·033 | ·00792 | ·076 | ·02729 | ·119 | ·05274 | ·162 | ·08258 |
| ·034 | ·00828 | ·077 | ·02782 | ·120 | ·05338 | ·163 | ·08332 |
| ·035 | ·00864 | ·078 | ·02836 | ·121 | ·05404 | ·164 | ·08406 |
| ·036 | ·00901 | ·079 | ·02889 | ·122 | ·05469 | ·165 | ·08480 |
| ·037 | ·00939 | ·080 | ·02943 | ·123 | ·05535 | ·166 | ·08554 |
| ·038 | ·00977 | ·081 | ·02997 | ·124 | ·05600 | ·167 | ·08629 |
| ·039 | ·01015 | ·082 | ·03053 | ·125 | ·05666 | ·168 | ·08704 |
| ·040 | ·01054 | ·083 | ·03108 | ·126 | ·05733 | ·169 | ·08778 |
| ·041 | ·01093 | ·084 | ·03163 | ·127 | ·05799 | ·170 | ·08854 |
| ·042 | ·01133 | ·085 | ·03219 | ·128 | ·05866 | ·171 | ·08929 |
| ·043 | ·01173 | ·086 | ·03275 | ·129 | ·05933 | ·172 | ·09004 |
| ·044 | ·01214 | ·087 | ·03331 | ·130 | ·06000 | ·173 | ·09080 |
| ·045 | ·01255 | ·088 | ·03385 | ·131 | ·06067 | ·174 | ·09155 |
| ·046 | ·01297 | ·089 | ·03444 | ·132 | ·06135 | ·175 | ·09231 |
| ·047 | ·01340 | ·090 | ·03501 | ·133 | ·06203 | ·176 | ·09307 |
| ·048 | ·01382 | ·091 | ·03538 | ·134 | ·06271 | ·177 | ·09383 |
| ·049 | ·01425 | ·092 | ·03616 | ·135 | ·06339 | ·178 | ·09460 |
| ·050 | ·01468 | ·093 | ·03674 | ·136 | ·06407 | ·179 | ·09537 |
| ·051 | ·01512 | ·094 | ·03732 | ·137 | ·06476 | ·180 | ·09613 |
| ·052 | ·01556 | ·095 | ·03790 | ·138 | ·06545 | ·181 | ·09690 |
| ·053 | ·01601 | ·096 | ·03850 | ·139 | ·06614 | ·182 | ·09767 |
| ·054 | ·01646 | ·097 | ·03909 | ·140 | ·06683 | ·183 | ·09845 |
| ·055 | ·01691 | ·098 | ·03968 | ·141 | ·06753 | ·184 | ·09922 |
| ·056 | ·01737 | ·099 | ·04028 | ·142 | ·06822 | ·185 | ·09999 |
| ·057 | ·01783 | ·100 | ·04087 | ·143 | ·06892 | ·186 | ·10077 |
| ·058 | ·01830 | ·101 | ·04148 | ·144 | ·06963 | ·187 | ·10153 |
| ·059 | ·01877 | ·102 | ·04208 | ·145 | ·07033 | ·188 | ·10233 |

| Height. | Area. | Height. | Area. | Height. | Area. | Height. | Area. |
|---|---|---|---|---|---|---|---|
| ·189 | ·10317 | ·232 | ·13815 | ·275 | ·17554 | ·318 | ·21480 |
| ·190 | ·10390 | ·233 | ·13899 | ·276 | ·17644 | ·319 | ·21573 |
| ·191 | ·10469 | ·234 | ·13984 | ·277 | ·17733 | ·320 | ·21667 |
| ·192 | ·10547 | ·235 | ·14069 | ·278 | ·17823 | ·321 | ·21760 |
| ·193 | ·10626 | ·236 | ·14154 | ·279 | ·17912 | ·322 | ·21853 |
| ·194 | ·10705 | ·237 | ·14239 | ·280 | ·18002 | ·323 | ·21947 |
| ·195 | ·10784 | ·238 | ·14324 | ·281 | ·18092 | ·324 | ·22040 |
| ·196 | ·10864 | ·239 | ·14409 | ·282 | ·18182 | ·325 | ·22134 |
| ·197 | ·10943 | ·240 | ·14494 | ·283 | ·18272 | ·326 | ·22228 |
| ·198 | ·11023 | ·241 | ·14580 | ·284 | ·18362 | ·327 | ·22322 |
| ·199 | ·11102 | ·242 | ·14665 | ·285 | ·18452 | ·328 | ·22415 |
| ·200 | ·11182 | ·243 | ·14752 | ·286 | ·18542 | ·329 | ·22509 |
| ·201 | ·11262 | ·244 | ·14837 | ·287 | ·18633 | ·330 | ·22603 |
| ·202 | ·11343 | ·245 | ·14923 | ·288 | ·18723 | ·331 | ·22697 |
| ·203 | ·11423 | ·246 | ·15009 | ·289 | ·18814 | ·332 | ·22792 |
| ·204 | ·11504 | ·247 | ·15096 | ·290 | ·18905 | ·333 | ·22886 |
| ·205 | ·11584 | ·248 | ·15182 | ·291 | ·18996 | ·334 | ·22980 |
| ·206 | ·11665 | ·249 | ·15268 | ·292 | ·19086 | ·335 | ·23074 |
| ·207 | ·11746 | ·250 | ·15355 | ·293 | ·19177 | ·336 | ·23169 |
| ·208 | ·11827 | ·251 | ·15442 | ·294 | ·19268 | ·337 | ·23263 |
| ·209 | ·11908 | ·252 | ·15528 | ·295 | ·19360 | ·338 | ·23358 |
| ·210 | ·11990 | ·253 | ·15615 | ·296 | ·19451 | ·339 | ·23453 |
| ·211 | ·12071 | ·254 | ·15702 | ·297 | ·19543 | ·340 | ·23547 |
| ·212 | ·12153 | ·255 | ·15789 | ·298 | ·19634 | ·341 | ·23642 |
| ·213 | ·12235 | ·256 | ·15876 | ·299 | ·19725 | ·342 | ·23737 |
| ·214 | ·12317 | ·257 | ·15964 | ·300 | ·19817 | ·343 | ·23832 |
| ·215 | ·12399 | ·258 | ·16051 | ·301 | ·19908 | ·344 | ·23927 |
| ·216 | ·12481 | ·259 | ·16139 | ·302 | ·20000 | ·345 | ·24025 |
| ·217 | ·12563 | ·260 | ·16226 | ·303 | ·20092 | ·346 | ·24117 |
| ·218 | ·12646 | ·261 | ·16314 | ·304 | ·20184 | ·347 | ·24212 |
| ·219 | ·12729 | ·262 | ·16402 | ·305 | ·20276 | ·348 | ·24307 |
| ·220 | ·12811 | ·263 | ·16490 | ·306 | ·20368 | ·349 | ·24403 |
| ·221 | ·12894 | ·264 | ·16578 | ·307 | ·20460 | ·350 | ·24498 |
| ·222 | ·12977 | ·265 | ·16666 | ·308 | ·20553 | ·351 | ·24593 |
| ·223 | ·13060 | ·266 | ·16755 | ·309 | ·20645 | ·352 | ·24689 |
| ·224 | ·13144 | ·267 | ·16843 | ·310 | ·20738 | ·353 | ·24784 |
| ·225 | ·13227 | ·268 | ·16932 | ·311 | ·20830 | ·354 | ·24880 |
| ·226 | ·13311 | ·269 | ·17020 | ·312 | ·20923 | ·355 | ·24976 |
| ·227 | ·13395 | ·270 | ·17109 | ·313 | ·21015 | ·356 | ·25071 |
| ·228 | ·13478 | ·271 | ·17198 | ·314 | ·21108 | ·357 | ·25167 |
| ·229 | ·13562 | ·272 | ·17287 | ·315 | ·21201 | ·358 | ·25263 |
| ·230 | ·13646 | ·273 | ·17376 | ·316 | ·21294 | ·359 | ·25359 |
| ·231 | ·13731 | ·274 | ·17465 | ·317 | ·21387 | ·360 | ·25455 |

| Height. | Area. | Height. | Area. | Height. | Area. | Height. | Area. |
|---|---|---|---|---|---|---|---|
| ·361 | ·25551 | ·391 | ·28457 | ·421 | ·31403 | ·451 | ·34378 |
| ·362 | ·25647 | ·392 | ·28554 | ·422 | ·31502 | ·453 | ·34577 |
| ·363 | ·25743 | ·393 | ·28652 | ·423 | ·31600 | ·455 | ·34776 |
| ·364 | ·25839 | ·394 | ·28750 | ·424 | ·31699 | ·457 | ·34975 |
| ·365 | ·25936 | ·395 | ·28848 | ·425 | ·31798 | ·459 | ·35174 |
| ·366 | ·26032 | ·396 | ·28955 | ·426 | ·31897 | ·462 | ·35474 |
| ·367 | ·26128 | ·397 | ·29043 | ·427 | ·31996 | ·464 | ·35673 |
| ·368 | ·26225 | ·398 | ·29141 | ·428 | ·32095 | ·466 | ·35873 |
| ·369 | ·26321 | ·399 | ·29239 | ·429 | ·32194 | ·468 | ·36072 |
| ·370 | ·26418 | ·400 | ·29337 | ·430 | ·32293 | ·470 | ·36272 |
| ·371 | ·26514 | ·401 | ·29435 | ·431 | ·32392 | ·471 | ·36371 |
| ·372 | ·26611 | ·402 | ·29533 | ·432 | ·32491 | ·473 | ·36571 |
| ·373 | ·26708 | ·403 | ·29631 | ·433 | ·32590 | ·475 | ·36771 |
| ·374 | ·26805 | ·404 | ·29729 | ·434 | ·32689 | ·477 | ·36971 |
| ·375 | ·26901 | ·405 | ·29827 | ·435 | ·32788 | ·479 | ·37170 |
| ·376 | ·26998 | ·406 | ·29926 | ·436 | ·32887 | ·482 | ·37470 |
| ·377 | ·27095 | ·407 | ·30024 | ·437 | ·32987 | ·484 | ·37670 |
| ·378 | ·27192 | ·408 | ·30122 | ·438 | ·33086 | ·486 | ·37870 |
| ·379 | ·27289 | ·409 | ·30220 | ·439 | ·33185 | ·488 | ·38070 |
| ·380 | ·27386 | ·410 | ·30319 | ·440 | ·33284 | ·490 | ·38270 |
| ·381 | ·27483 | ·411 | ·30417 | ·441 | ·33384 | ·491 | ·38370 |
| ·382 | ·27580 | ·412 | ·30516 | ·442 | ·33483 | ·492 | ·38470 |
| ·383 | ·27678 | ·413 | ·30614 | ·443 | ·33582 | ·493 | ·38570 |
| ·384 | ·27775 | ·414 | ·30712 | ·444 | ·33682 | ·494 | ·38670 |
| ·385 | ·27872 | ·415 | ·30811 | ·445 | ·33781 | ·495 | ·38770 |
| ·386 | ·27969 | ·416 | ·30910 | ·446 | ·33880 | ·496 | ·38870 |
| ·387 | ·28070 | ·417 | ·31008 | ·447 | ·33980 | ·497 | ·38970 |
| ·388 | ·28164 | ·418 | ·31107 | ·448 | ·34079 | ·498 | ·39070 |
| ·389 | ·28262 | ·419 | ·31205 | ·449 | ·34179 | ·499 | ·39170 |
| ·390 | ·28359 | ·420 | ·31304 | ·450 | ·34278 | ·500 | ·39270 |

## TABLE 11.—LENGTHS OF SEMI-ELLIPTIC ARCS. (J. C. Trautwine.)*

(SPAN = 1).

| Height. | Length. | Height. | Length. | Height. | Length. | Height. | Length. |
|---|---|---|---|---|---|---|---|
| ·02 | 1·003 | ·045 | 1·014 | ·07 | 1·029 | ·095 | 1·046 |
| ·025 | 1·004 | ·05 | 1·017 | ·075 | 1·032 | ·100 | 1·051 |
| ·03 | 1·006 | ·055 | 1·020 | ·08 | 1·036 | ·105 | 1·055 |
| ·035 | 1·008 | ·06 | 1·023 | ·085 | 1·039 | ·110 | 1·059 |
| ·04 | 1·011 | ·065 | 1·026 | ·09 | 1·043 | ·115 | 1·064 |

* See Introduction, *ante* p. 7.

| Height. | Length. | Height. | Length. | Height. | Length. | Height. | Length. |
|---|---|---|---|---|---|---|---|
| ·120 | 1·069 | ·220 | 1·177 | ·315 | 1·298 | ·410 | 1·434 |
| ·125 | 1·074 | ·225 | 1·183 | ·320 | 1·305 | ·415 | 1·441 |
| ·130 | 1·079 | ·230 | 1·189 | ·325 | 1·312 | ·420 | 1·449 |
| ·135 | 1·084 | ·235 | 1·196 | ·330 | 1·319 | ·425 | 1·456 |
| ·140 | 1·089 | ·240 | 1·202 | ·335 | 1·325 | ·430 | 1·464 |
| ·145 | 1·094 | ·245 | 1·207 | ·340 | 1·332 | ·435 | 1·471 |
| ·150 | 1·099 | ·250 | 1·213 | ·345 | 1·339 | ·440 | 1·479 |
| ·155 | 1·104 | ·255 | 1·219 | ·350 | 1·346 | ·445 | 1·486 |
| ·160 | 1·109 | ·260 | 1·226 | ·355 | 1·353 | ·450 | 1·494 |
| ·165 | 1·115 | ·265 | 1·233 | ·360 | 1·361 | ·455 | 1·501 |
| ·170 | 1·120 | ·270 | 1·239 | ·365 | 1·368 | ·460 | 1·509 |
| ·175 | 1·125 | ·275 | 1·245 | ·370 | 1·375 | ·465 | 1·517 |
| ·180 | 1·131 | ·280 | 1·252 | ·375 | 1·382 | ·470 | 1·524 |
| ·185 | 1·137 | ·285 | 1·259 | ·380 | 1·390 | ·475 | 1·532 |
| ·190 | 1·142 | ·290 | 1·265 | ·385 | 1·397 | ·480 | 1·540 |
| ·195 | 1·147 | ·295 | 1·272 | ·390 | 1·404 | ·485 | 1·547 |
| ·200 | 1·153 | ·300 | 1·279 | ·395 | 1·412 | ·490 | 1·555 |
| ·205 | 1·159 | ·305 | 1·285 | ·400 | 1·419 | ·495 | 1·563 |
| ·210 | 1·165 | ·310 | 1·292 | ·405 | 1·426 | ·500 | 1·571 |
| ·215 | 1·171 | | | | | | |

## MEASUREMENT OF SURFACES AND SOLIDS.

### Plane Surfaces.

*The area of a triangle* is equal to half the product of the base by the perpendicular height.

*The area of a parallelogram* is equal to the product of the length by the height.

*The area of a trapezoid* (a parallel-sided figure of four sides, having two sides not parallel) is equal to the product of half the sum of the parallel sides by the distance between them.

*The area of any quadrilateral* or *four-sided figure*, is found by dividing the figure into two triangles; the sum of the areas of which is the area of the quadrilateral.

*The area of a square* or a *rhombus* (an oblique-angled equal-sided parallelogram) is equal to half the product of the diagonals.

*The area of a polygon* or *many-sided figure* is found by dividing the figure into triangles and trapezoids; the sum of the areas of these is the area of the figure.

*The area of a regular polygon* is half the product found by

multiplying the length of the side by the number of sides and by the perpendicular from the centre to one of the sides. In Table 12, columns 3 and 4 respectively are the lengths of the perpendiculars and the areas of the figures, when the length of the side is equal to 1; also the areas of polygons having an even number of sides, when the width across, between parallel sides (or twice the perpendicular length),

TABLE 12.—REGULAR POLYGONS.

| Designation of Polygon. 1. | Number of Sides. 2. | Perpendicular. (Side=1.) 3. | Area. (Side=1.) 4. | Area. (Width across =1.) 5. |
|---|---|---|---|---|
| Equilateral triangle. | 3 | 0·2887 | 0·4330 | ... |
| Square . . . | 4 | 0·5000 | 1·0000 | 1·0000 |
| Pentagon . . . | 5 | 0·6882 | 1·7205 | ... |
| Hexagon . . . | 6 | 0·8660 | 2·5981 | 0·8661 |
| Heptagon . . . | 7 | 1·0383 | 3·6339 | ... |
| Octagon . . . | 8 | 1·2071 | 4·8284 | 0·8284 |
| Nonagon . . . | 9 | 1·3737 | 6·1818 | ... |
| Decagon . . . | 10 | 1·5388 | 7·6942 | 0·8123 |
| Undecagon . . . | 11 | 1·7028 | 9·3656 | ... |
| Dodecagon . . . | 12 | 1·8660 | 11·1962 | 0·8082 |
| Circle . . . | infinite | infinite | infinite | 0·7854 |

is equal to 1. A line is added to the table showing the relation of the circle as a polygon having an indefinitely great number of sides.

When the length of the side is other than 1, the perpendiculars and areas are to be calculated by squaring the given value of the side and multiplying the square by the corresponding coefficient in the table: column 3 for the perpendicular, column 4 for the area.

When the width across is other than 1, the area is to be calculated by squaring the value of the given width and multiplying the square by the corresponding coefficient in column 5.

A Regular Polygon may be inscribed in a circle. To supply a means of dividing the circumference of a circle into any number of equal parts, with a view to inscription of a polygon, the annexed tablet of angles at the centre subtended by the sides of polygons, expressed in degrees, is of general utility. Set off round the centre of the circle a succession of angles by means of the protractor, equal to the angle in the table due to a given number of sides. The radii so drawn divide the cir-

cumference into the same number of parts. The triangles thus formed are the elementary triangles of the polygon.

TABLE 13.—POLYGONAL ANGLES AT THE CENTRE.

| Number of Sides of Polygon. | Elementary Angle at Centre. | Number of Sides of Polygon. | Elementary Angle at Centre. |
|---|---|---|---|
| Sides. | Degrees. | Sides. | Degrees. |
| 3 | 120 | 12 | 30 |
| 4 | 90 | 13 | $27\frac{9}{13}$ |
| 5 | 72 | 14 | $25\frac{5}{7}$ |
| 6 | 60 | 15 | 24 |
| 7 | $51\frac{3}{7}$ | 16 | $22\frac{1}{2}$ |
| 8 | 45 | 17 | $21\frac{3}{17}$ |
| 9 | 40 | 18 | 20 |
| 10 | 36 | 19 | 19 (exactly $18\frac{18}{19}$) |
| 11 | $32\frac{8}{11}$ | 20 | 18 |

### Circle.

*The circumference of a circle* is 3·1416 times the diameter; or, approximately, $3\frac{1}{7}$ times. Or, the diameter is to the circumference as 7 to 22, approximately; or as 113 to 355. Trigonometrically, the circle is divisible into 360 degrees.

When the *diameter* is 1, the area is equal to ·7854, or approximately 4-5ths. The area of a circle of a given diameter is found by multiplying the square of the diameter by ·7854.

*The length of an arc of a circle* is found by multiplying the number of degrees in the arc by the radius, and by ·01745. Or, approximately, by subtracting the chord of the arc from eight times the chord of half the arc; and taking one-third of the remainder.

*The area of a sector of a circle* is equal to the product of half the length of the arc of the sector by the radius. Or, multiply the number of degrees in the arc by the square of the radius, and by ·008727.

*The area of a segment of a circle.* Find the area of the sector which has the same arc as the segment; also the area of the triangle formed by the radial sides of the sector and the chord of the arc. The difference or the sum of these areas is the area of the segment, according as it is less or greater than a semicircle.

*The area of a ring.* Multiply the sum of the outer and inner diameters by their difference and by ·7854.

*The area of a zone of a circle.* Find the areas of the two

segments cut off, and subtract the sum of these areas from the area of the whole circle, to give the area of the zone.

*The side of a square* equal in area to a given circle is equal to the product of the diameter by ·8862.

*The side of a square inscribed* in a circle is equal to the product of the diameter by ·7071.

*The area of an inscribed square* is equal to the product of the area of the circle by ·6366.

*The diameter of a circle equal in area* to a given square is equal to the product of the side of the square by 1·1284, or $1\frac{1}{8}$ approximately.

*The diameter of a circumscribing circle* is equal to the product of the side of the given square by 1·4142.

*The area of a circumscribing circle* is equal to the product of the area of the given square by 1·5708.

## Ellipse.

*The circumference of an ellipse* is equal to the product of the square root of half the sum of the squares of the two axes by 3·1416.

This rule is approximate. Mr. Trautwine proposes the following formula for the circumference of an ellipse, as more nearly exact, and sufficiently so for ordinary purposes. When the longer axis, D, is not more than five times the length of the shorter axis, $d$,

$$\text{Circumference} = 3{\cdot}1416\sqrt{\frac{D^2 + d^2}{2} - \frac{(D - d)^2}{8{\cdot}8}} \quad . \quad (1)$$

When the longer axis is more than five lengths of the shorter axis, the divisor 8·8 under the sign is to be replaced by the following divisors :—

| | Divisor. |
|---|---|
| When the longer axis is 6 times the shorter | 9 |
| ,, ,, 7 ,, ,, | 9·2 |
| ,, ,, 8 ,, ,, | 9·3 |
| ,, ,, 9 ,, ,, | 9·35 |
| ,, ,, 10 ,, ,, | 9·4 |
| ,, ,, 12 ,, ,, | 9·5 |
| ,, ,, 14 ,, ,, | 9·6 |
| ,, ,, 16 ,, ,, | 9·68 |
| ,, ,, 18 ,, ,, | 9·75 |
| ,, ,, 20 ,, ,, | 9·8 |
| ,, ,, 25 ,, ,, | 9·87 |
| ,, ,, 30 ,, ,, | 9·92 |
| ,, ,, 40 ,, ,, | 9·98 |
| ,, ,, 50 ,, ,, | 10·00 |

*The area of an ellipse* is equal to the product of the two axes by ·7854.

*The area of a segment of an ellipse*, the base of which is parallel to one of the axes of the ellipse. Divide the height of the segment by the axis of which it is a part, and find the area of a circular segment, in a table of circular segments, of which the height is equal to the quotient; multiply the area thus found by the two axes of the ellipse successively; the product is the area.

### Curvilineal Figures.

*The area of any curvilineal figure* bounded at the ends by parallel straight lines by Simpson's rule. Divide the length of the figure into any even number of equal parts, at the common distance D apart, and draw ordinates through the points of division, to touch the boundary lines. Add together the first and last ordinates, and call the sum A; add together the even ordinates, and call the sum B; add together the odd ordinates, except the first and last, and call the sum C. Then,

$$\text{area of the figure} = \frac{A + 4\,B + 2\,C}{3} \times D \quad . \quad (2)$$

*2nd Method.*—Divide the figure into any sufficient number, $n$, of equal parts; add together the first and last ordinates, making the sum A; add together all the intermediate ordinates, making the sum B. Putting L for the length of the figure. Then,

$$\text{area of the figure} = \frac{A + 2\,B}{2\,n} \times L \quad . \quad . \quad (3)$$

*3rd Method.*—Divide the figure into a sufficient number of equal parts, as before. Add together the mean depths of the several divisions, and divide the sum by the number of divisions, to give the average depth; multiply the average depth by the total length, to give the area.

The figure may, otherwise, be divided into two half-parts, one at each end, and a number of whole parts intermediately. The sum of the ordinates, excepting the extreme ordinates, divided by the number of them, gives the average depth, and the product of this by the length, gives the area.

The figures may be bounded at the ends by curves or angles. In this case, the extreme ordinates become nothing.

### Solids.

There are five species of regular solids, bounded by regular polygons, of which particulars are given in the annexed table:—

TABLE 14.—REGULAR SOLIDS.

| Designation of Solid. 1 | Number and Designation of Sides. 2 | Superficial Area (Edge = 1) 3 | Contents (Edge = 1) 4 |
|---|---|---|---|
| Tetrahedron . | 4 equilateral triangles . | 1·7320 | 0·1178 |
| Hexahedron, or Cube | 6 squares . . . | 6·0000 | 1·0000 |
| Octahedron . . | 8 equilateral triangles . | 3·4641 | 0·4714 |
| Dodecahedron | 12 pentagons . . . | 20·6458 | 7·6631 |
| Icosahedron . | 20 equilateral triangles. | 8·6603 | 2·1817 |

Regular solids may be circumscribed by spheres; and spheres may be inscribed in regular solids.

*To find the total area of surface of a regular solid*, multiply the square of the length of the edge by the tabular number given in column 3 of the table.

*To find the contents of a regular solid*, multiply the cube of the length of the edge by the tabular number in column 4 of the table.

The four leading solids are the cube, the cylinder, the sphere, and the cone. A cubic foot contains

1,728 cubic inches, or
2,200 cylindrical inches, or
3,300 spherical inches, or
6,600 conical inches.

These values supply an easy practical rule for finding, by proportion, the capacities of the "three round bodies."

*The surface of a cylinder, or of a prism*, is equal to the product of the perimeter of one end by the height; plus twice the area of one end.

*The cubic content of a cylinder, or of a prism*, is equal to the product of the area of the base by the length or height of the cylinder.

*The surface of a sphere* is equal to the product of the square of the diameter by 3·1416.

It is equal to four times the area of one of its great circles.

It is equal to the convex surface of its circumscribing cylinder.

The surfaces of spheres are to each other as the squares of their diameters.

*The curve surface of a segment, or a zone of a sphere*, is equal to the product of the diameter of the sphere by the height of the segment or zone, and by 3·1416. The curve

surfaces of segments or zones of a sphere are in the ratio of their heights.

*The content of a sphere* is equal to the product of the cube of the diameter by ·5236. Or, it is the product of the surface by one-sixth of the diameter.

The content of a sphere is two-thirds of that of the circumscribing cylinder.

The contents of spheres are to each other as the cubes of the diameters.

*The cubic content of a segment of a sphere.* From three times the diameter of the sphere subtract twice the height of the segment; multiply the difference by the square of the height, and by ·5236. Or, to three times the square of the radius of the base of the segment, add the square of its height; and multiply the sum by the height, and by ·5236.

*The cubic content of a zone of a sphere.* To the sum of the squares of the radii of the ends add one-third of the square of the height; multiply the sum by the height, and by 1·5708.

*The cubic content of a spheroid* is equal to the product of the square of the revolving axis by the fixed axis, and by ·5236. The content of a spheroid is two-thirds of that of the circumscribing cylinder.

*The cubic content of a segment of a spheroid.* 1. When the base is parallel to the revolving axis, multiply the difference between three times the fixed axis and twice the height of the segment, by the square of the height, and by ·5236. Multiply the product by the square of the revolving axis, and divide by the square of the fixed axis.

2. When the base is perpendicular to the revolving axis, multiply the difference between three times the revolving axis and twice the height of the segment, by the square of the height, and by ·5236. Multiply the product by the length of the fixed axis, and divide by the length of the revolving axis.

*The cubic content of the middle frustum of a spheroid.* 1. When the ends are circular, or parallel to the revolving axis. To twice the square of the middle diameter, add the square of the diameter of one end; multiply the sum by the length of the frustum, and by ·2618.

2. When the ends are elliptical, or perpendicular to the revolving axis. To twice the product of the transverse and conjugate diameters of the middle section, add the product of the transverse and conjugate diameters of one end; multiply the sum by the length of the frustum, and by ·2618.

*The cubic content of a parabolic conoid* (generated by the revolution of a parabola on its axis). Multiply the area of the base by half the height.

Or, multiply the square of the diameter of the base by the height, and by ·392.

*The cubic content of a frustum of a parabolic conoid.* Multiply half the sum of the areas of the two ends by the height.

*The cubic content of a parabolic spindle* (generated by the revolution of a parabola on its base). Multiply the square of the middle diameter by the length, and by ·4189.

The content of a parabolic spindle is to that of a cylinder of the same height and diameter, as 8 to 15.

*The cubic content of the middle frustum of a parabolic spindle.* Add together 8 times the square of the maximum diameter, 3 times the square of the end diameter, and 4 times the product of the diameters; multiply the sum by the length of the frustum, and by ·05236.

This rule is applicable for calculating the content of casks of parabolic form.

*To find the cubic content of a cask of any form.* Add together 39 times the square of the bung diameter, 25 times the square of the head diameter, and 26 times the product of the diameters; multiply the sum by the length, and divide by 31,773 for the content in imperial gallons.

This rule was framed by Dr. Hutton, on the supposition that the middle third of the length of the cask was a frustum of a parabolic spindle, and each outer third was a frustum of a cone.

*To find the ullage of a cask*, the quantity of liquor in it when it is not full. 1. For a *lying cask.* Divide the number of wet or dry inches by the bung diameter in inches. If the quotient is less than ·5, deduct from it one-fourth part of what it wants of ·5. If it exceeds ·5, add to it one-fourth part of the excess above ·5. Multiply the remainder or the sum by the whole content of the cask. The product is the quantity of liquor in the cask, in gallons, when the dividend is *wet* inches or the empty space, if *dry* inches.

2. For a *standing cask.* Divide the number of wet or dry inches by the length of the cask. If the quotient exceeds ·5, add to it one-tenth of its excess above ·5; if less than ·5, subtract from it one-tenth of what it wants of ·5. Multiply the sum or the remainder by the whole content of the cask. The product is the quantity of liquor in the cask, when the dividend is wet inches; or the empty space if dry inches.

*The surface of a cone or of a pyramid* is equal to the product of the perimeter of the base by half the slant height, plus the area of the base.

*The content of a cone or of a pyramid* is equal to the product of the area of the base by one-third of the perpendicular height.

*The surface of a frustum of a cone or a pyramid* is equal to the product of the sum of the perimeters of the ends by half the slant height, plus the areas of the ends.

*The content of a frustum of a cone or a pyramid* is found by adding together the areas of the ends and the mean proportional between them (the square root of their product), and multiplying the sum by one-third of the perpendicular height.

Or, in the case of a conical frustum, add together the squares of the diameters and the product of the diameters and multiply the sum by ·7854, and by one-third of the height.

*The content of a wedge* is found by adding together twice the length of the base and the length of the edge, and multiplying the sum by the breadth of the base, and by one-sixth of the height.

*The content of a prismoid* (a solid having three or more inclined sides, and similar parallel ends) is found by adding together the areas of the ends, and four times the intermediate sectional area equally distant from the ends; and multiplying the sum by one-sixth of the length.

*The content of an irregular solid* may be found by dividing it into parts measurable by the ordinary rules, and adding together the contents of them; the sum is the content of the solid.

*Piles of equal spheres or balls.* Ranged usually in pyramidal piles, on a square or a triangular base; or in oblong piles on a rectangular base:—

1. *To find the number of balls in a pile on a square base.* Let $n =$ the number of horizontal strata or layers of spheres in the piles, comprising the highest stratum, which consists of one sphere. The number, S, of spheres is

$$S=\frac{2n^3+3n^2+n}{6} \quad . \quad . \quad . \quad . \quad (4)$$

The value $n$ expresses also the number of spheres in one side of the base. If, for example, $n=10$, the number of balls, S, is, by the formula, $(2{,}000+300+10)\div 6=385$.

2. *On a triangular base.*

$$S=\frac{n(n+1)(n+2)}{6} \quad . \quad . \quad . \quad (5)$$

If $n$ is equal to 10, S is equal to 220.

3. *Oblong pile on a rectangular base.* The uppermost stratum is a row of balls, say $m$ in number,

$$S=\frac{n(n+1)(3m+2n)-2}{6} \quad . \quad . \quad . \quad (6)$$

Supposing $m$ and $n$ each equal to 10, S is equal to 880.

## DESCRIPTION OF CIRCULAR SEGMENTS, CONIC SECTIONS AND CYCLOIDS.

*To describe a Circle passing through three given points*, when the Centre is not available. From the extreme points A, B, fig. 1, as centres describe arcs AH, BG. Through the third point C draw AE, BF. Divide AF and BE into any

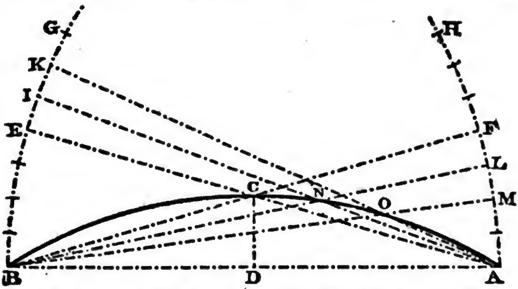



FIG. 1.—To describe a Circular Arc through three points.

convenient number of equal parts, and set off a series of equal parts of the same length on the upper portions of the arcs, beyond the points E, F. Draw straight lines BL, BM, &c., to the divisions in AF; and AI, AK, &c., to the division in EG. The successive intersections at N, O, &c., of these lines, are points in the circle required, between the given points A and C, which may be traced in accordingly. Similarly, the remaining part of the curve may be described.

*2nd Method.* Let A, D, B, fig. 2, be the given points. Draw AB, AD, and DB; and *ef* parallel to AB. Divide AD into a number of equal parts, at 1, 2, 3, &c., and from D

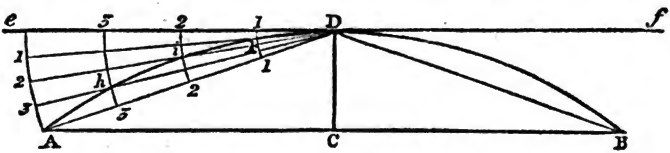



FIG. 2.—To describe a Circular Arc through three points.

describe arcs through these points. Divide the arc A*e* into the same number of equal parts, and draw straight lines from D to the points of division. The intersections of these lines successively with the arcs 1, 2, 3, &c., are points in the circle.

*Note.*—The second method is not exact, but it is sufficiently near to exactness for arcs less than one-fourth of a circle.

The Ellipse is a Curve such that the sum of the distances of any point in the curve from two fixed points or foci, is constant.

*To describe an Ellipse*, when the length and width are given. On the centre C, fig. 3, with AE as radius, cut the axis AB at F and G, the foci. Fix a couple of pins into the axis at F and G, and loop a thread or cord upon them equal in length to the axis AB, so as, when stretched, to reach to the extremity C of the conjugate axis. With a pencil or draw-point inside the cord, as at H, guide the pencil in tension about the pins F and G, and so describe the ellipse.

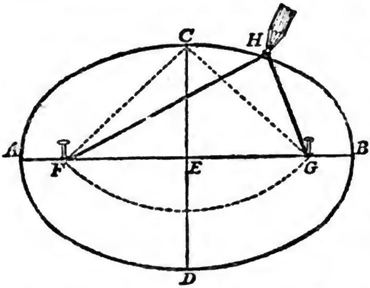



FIG. 3.—To describe an Ellipse.

*2nd Method.* Bisect the transverse axis, fig. 4 at C, and through C draw the perpendicular DE, making CD and CE each equal to half the conjugate axis. From D or E, with the radius AC cut the transverse axis at F, F′, for the foci. Divide AC into any number of parts at 1, 2, 3, &c. With the radius A1, on F and F′ as centres, describe arcs; and with the radius B1 on the same centres, cut these arcs, as shown. Repeat the operation for the other points of division of the transverse axis. The series of intersections thus made are points in the curve, through which the curve may be traced.

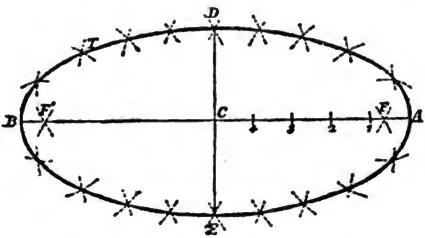



Fig. 4.—To describe an Ellipse.

*3rd Method* (approximate). With arcs of two radii, fig. 5. Lay down the axes AB and CD, and set off O*a* and O*c* equal to the difference of the lengths of the axes. Draw *ac* and set off half of *ac* to *d*, and O*e* equal to O*d*. Draw *di*, *ei*, and parallels intersecting at *m*. From the centres *m* and *i*, describe arcs through C and D; and from *d* and *e*, describe arcs through A and B. The four arcs form the ellipse.

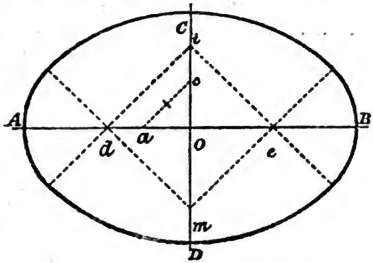


FIG. 5.—To describe an Ellipse.

*Note.* — This method is applicable when the conjugate axis is at least two-thirds of the transverse axis.

*4th Method* (approximate). With arcs of three radii, fig 6.

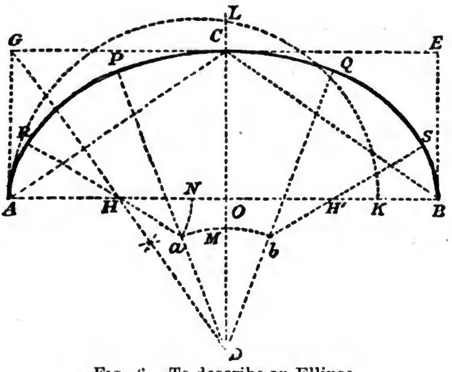


FIG. 6.—To describe an Ellipse.

On the transverse axis AB, draw the rectangle BG, on the height OC, of the semi-conjugate axis. To the diagonal AC draw the perpendicular GHD; set off OK equal to OC, and describe a semicircle on AK, and produce OC to L. Set off OM equal CL, and on D describe an arc with the radius DM. On A with radius OL, cut this arc at A. The five centres D, *a*, *b*, H, H′, are found, from which the arcs are described to form the ellipse.

*Note.*—This process works well for nearly all proportions of ellipses.

The parabola is a curve such that the distance of any point in the curve from a fixed point, the focus, is equal to its distance from a straight line, the directrix.

*To describe a Parabola*, when an absciss and its ordinate, or the height and the base, are given. Bisect the given ordinate BC, fig. 7, at *a*; draw A*a*, and then *ab* perpendicular to it, meeting the axis at *b*. Set off A*e*, AF, each equal to B*b*, and draw K*e*L at right angles to the axis. Then KL is the directrix and F is the focus. Through F and any number of points *o*, *o*, &c., in the axis, draw double ordinates *non*, &c., and on the centre F, with the radii F*e*, *oe*, &c., cut the respective ordinates at E, G, *n*, *n*, &c. The curve is traced through these points of intersection.

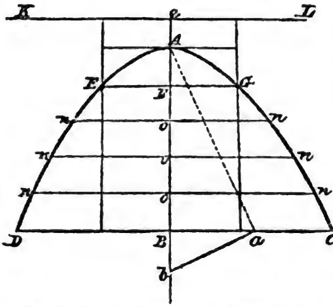


FIG. 7.—To describe a Parabola.

*2nd Method.* Place a straight-edge to the directrix EN, fig. 8, and apply to it a square LEG. Fasten to the end G one end of a thread or cord, shown in dot-lining, equal in length to the edge EG, and attach the other end to the focus F. Slide the square along the straight-edge, holding the cord taut against the edge of the square by a drawpoint or pencil D, by which the curve is described.

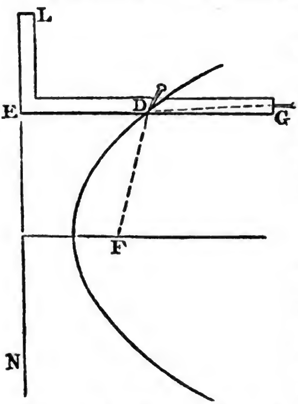


FIG. 8.—To describe a Parabola.

*3rd Method.* Through the vertex A, fig. 9, draw EF parallel to CD the base, and through C and D draw CE and DF parallel to the axis AB. Divide BC and BD into any number of equal parts, at *a*, *b*, &c., and divide CE and DF into the same number of equal parts. Through the points *a*, *b*, *c*, *d*, in the base CD, draw perpendiculars, and through *a*, *b*, *c*, *d* in CE and DF draw lines to the vertex A, cutting the perpendiculars at *e*, *f*, *g*, *h*. These are points the curve, which may be traced through them.

The nature of the parabola is such that the abscissæ vary in length as the squares of the ordinates. Inversely, the ordinates vary as the square roots of the abscissæ. By means of these

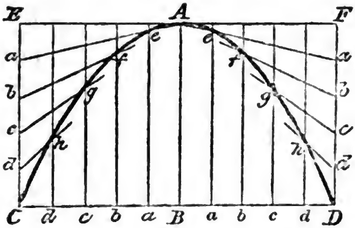



FIG. 9.—To describe a Parabola.

relations any number of points in the curve may be determined, and the curve constructed.

The hyperbola is a curve such that the difference of the distances of any point in the curve from two fixed points, the foci, is equal to a constant, the transverse axis. The vertices A, B, fig. 10, of opposite hyperbolas, are the heads of the

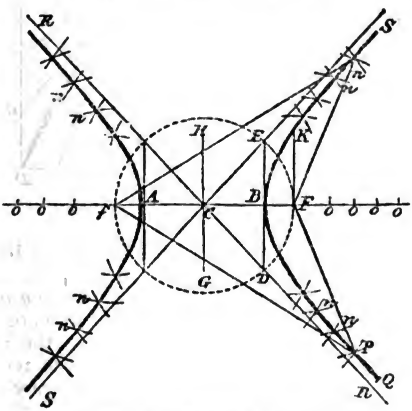



FIG. 10.—To describe a Hyperbola.

curves, in their axial lines. The transverse axis AB is the distance between the vertices. The conjugate axis GH passes through the centre C, at right angles to the transverse axis.

*To describe a Hyperbola.* Let the ends of two threads $f$PQ, FPQ, fig. 10, be fastened at the points $f$ and F, and passed through a small bead or pin P, and knotted together at Q. Take hold of Q and draw the threads taut; move the bead along the threads, and the point P will describe the curve.

2*nd Method.* When the base CD, height AB, and transverse axis AA′, fig. 11, are given. Divide the base CD into a number of equal parts on each side of the axis at *a*, *b*, &c.; and divide the parallels CE, DF, into the same number of equal parts at *a*, *b*, &c. From the points *a*, *b*, &c., in the base, draw lines to A′; and from the points *a*, *b*, &c., in the verticals, draw

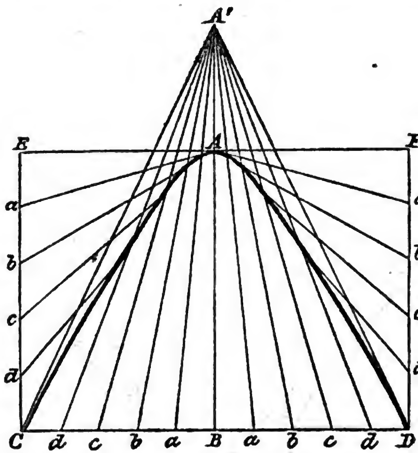



FIG. 11.—To describe a Hyperbola.

lines to A, cutting the respective lines from the base. Trace the curve through the intersections.

*To describe a Right-angled Hyperbola, given a point in the curve.* Let E, fig. 12, be a point in the curve, of which AB and AC, at right angles to each other, are the asymptotes. Draw the parallels DE and DC to complete the rectangle AE. Set off D*d* on the base line equal to AD, and draw the vertical *de*. Bisect AC at *b*, and draw *be* parallel to the base; the point of intersection, *e*, is a point in the curve. Similarly, bisecting A*b* at *c*, and A*c* at *n*; doubling A*d* to *d*′, and A*d*′ to *d*″; and completing the rectangles *d*′*e*′ and *d*″*e*″; and again bisecting and doubling; the points *e*′ and *e*″, and *e*‴ in the curve are found. By a like process of dividing and multiplying in-

versely, any additional number of points may be found, and the curve may be traced through the points.

This curve possesses the useful property that the elementary rectangles are equal in area.

The cycloid ADB, fig. 13, is the curved path described by

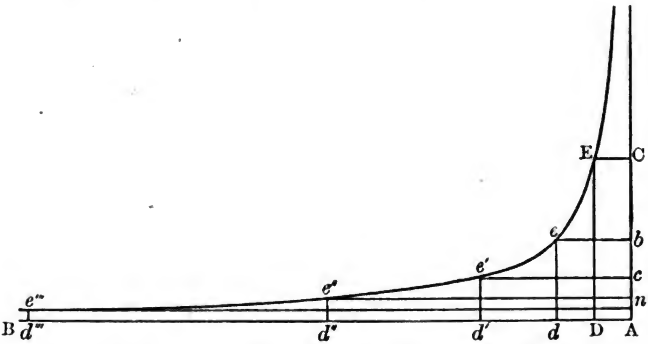



FIG. 12.—To describe a Right-Angled Hyperbola.

any point D in the circumference of a wheel or a circle DGC which rolls along a straight line. The base AB for a complete

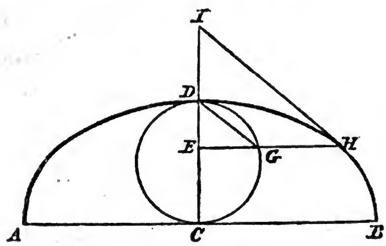



FIG. 13.—Cycloid.

revolution of the wheel, is equal in length to the circumference of the circle; the length of the curve is equal to four times the diameter of the circle; the area of the cycloid, ADBA, is equal to three times the area of the circle.

The exterior epicycloid ADB, fig. 14, is the curve described by any point in the circumference of one circle, DC, rolling over another circle, ACB, on the outside of the circumference.

The hypocycloid, or interior epicycloid, ADB, fig. 15, is the

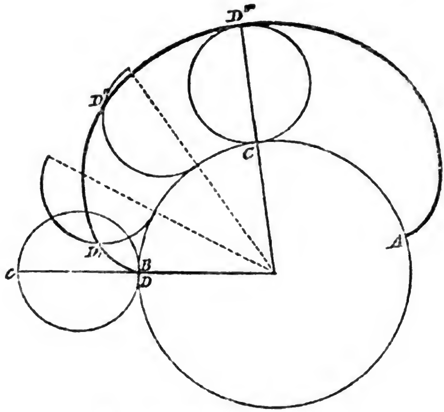



FIG. 14.—Exterior Epicycloid.

curve ADB described by a point in the circumference of a circle rolling on the inside of the circumference of another

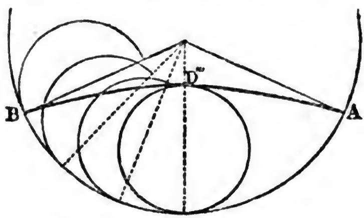



FIG. 15.—Interior Epicycloid.

circle. When the diameter of the rolling circle is equal to half the diameter of the fixed circle, the curve becomes a straight line, or a diameter of the fixed circle.

## WEIGHTS AND MEASURES.

THE yard and the pound are the units of English measure and weight.

The imperial standard yard is a solid square bar, 38 inches long, 1 inch square, of bronze or gun-metal, deposited in the Standards Department of the Board of Trade. The length of the yard is defined by lines inscribed on two gold plugs inserted near each end of the bar.

The imperial standard pound is a cylinder of platinum, nearly 1·35 inches in height, and 1·15 inches in diameter, having a groove or channel round it, near the top, by which it may be lifted.

Copies of the standard yard and the standard pound have been deposited in the Royal Mint and the Greenwich Observatory; copies have been immured in the New Palace at Westminster; and copies have been delivered to the Royal Society of London.

The unit or standard measure of capacity, for liquids as for dry goods, is the gallon, capable of containing ten imperial standard pounds weight of distilled water weighed in air against brass weights, at the temperature of 62° F., with the barometer at 30 inches. The standard measure is cylindrical, on a plane base, and the height is equal to the diameter.

The standard bushel, as a measure of capacity, is cylindrical, about 17·8 inches in diameter, with a plane base; the depth is half the diameter, about 8·9 inches. It has a capacity equal to 8 gallons.

In using an imperial measure of capacity, it is not to be heaped; but is either to be stricken with a round stick or cylindrical roller; or, if the article cannot be conveniently stricken, it is to be filled in all parts as nearly to the level of the brim as the size and shape of the article admits.

### LIST OF GAUGES DEPOSITED AT THE STANDARDS OFFICE BY SIR JOSEPH WHITWORTH.

1 set, External plane gauges, containing 91 sizes, from ·01 to 0·1, rising by ·001 inch.

6 sets, Internal and External Cylindrical gauges, containing the following fractional sizes :—

1 set containing 15 gauges from $\frac{1}{8}$ inch to 1 inch, increasing by $\frac{1}{16}$ inch.

1 ,, ,, 8 ,, ,, $1\frac{1}{8}$ inches to 2 inches, increasing by $\frac{1}{8}$ inch.

1 set containing 8 gauges from $2\frac{1}{8}$ inches to 3 inches, increasing by $\frac{1}{8}$ inch.
1 ,, ,, 8 .. .. $3\frac{1}{8}$ inches to 4 inches, increasing by $\frac{1}{8}$ inch.
1 ,, ,, 4 ,, .. $4\frac{1}{4}$ inches to 5 inches, increasing by $\frac{1}{4}$ inch.
1 ,, ,, 4 ,, .. $5\frac{1}{4}$ inches to 6 inches, increasing by $\frac{1}{4}$ inch.

6 sets, containing the following decimal sizes :—

1 set containing 15 gauges, sizes, 0·10, 0·15, 0·2, 0·3, 0·35, 0·4, 0·45, 0·55, 0·60, 0·65, 0·7, 0·8, 0·85, 0·9, 0·95 inch.
1 ,, ,, 8 ,, .. 1·1, 1·2, 1·3, 1·4, 1·6, 1·7, 1·8, 1·9 inches.
1 ,, ,, 8 ,, .. 2·1, 2·2, 2·3, 2·4, 2·6, 2·7, 2·8, 2·9 inches.
1 ,, ,, 8 ,, .. 3·1, 3·2, 3·3, 3·4, 3·6, 3·7, 3·8, 3·9 inches.
1 ,, ,, 4 ,, .. 4·2, 4·4, 4·6, 4·8 inches.
1 ,, ,, 4 ,, .. 5·2, 5·4, 5·6, 5·8 inches.

From 6 inches to 2 inches inclusive, the gauges are made of cast iron ; and below 2 inches they are made of steel.

The above collection of gauges is denominated as follows :—

(1.) Whitworth's External Cylindrical Gauges : external diameters in terms of the inch.

15 gauges from $\frac{1}{8}$ inch to 1 inch, increasing by sixteenths of an inch.

24 gauges from $1\frac{1}{8}$ inches to 4 inches, increasing by eighths of an inch.

8 gauges from $4\frac{1}{4}$ inches to 6 inches, increasing by quarters of an inch.

19 gauges from 0·1 inch to 1 inch, increasing by five one-hundredths of an inch.

30 gauges from 1·1 inches to 4 inches, increasing by tenths of an inch.

10 gauges from 4·2 inches to 6 inches, increasing by fifths of an inch.

(2.) Whitworth's Internal Cylindrical Gauges : internal diameters in terms of the inch : a repetition of section (1) preceding.

(3.) Whitworth's External Plane Gauges : thickness in terms of the inch.

91 gauges from ·01 inch to 0·1 inch, increasing by thousandths of an inch.

## TABLE 15.—ENGLISH MEASURES OF LENGTH.

| | | French Equivalents. |
|---|---|---|
| 12 lines, 72 points, 1000 mils | 1 inch | 25·4 millimetres. |
| 7·92 inches | 1 link | ·2012 metre. |
| 12 inches | 1 foot | ·3048 metre. |
| 3 feet | 1 yard | ·91439 ,, |
| 6 feet | 1 fathom | 1·82878 ,, |
| $5\frac{1}{2}$ yards | 1 rod, pole, or perch | 5·02915 ,, |
| 100 links, 66 feet | 1 chain | 20·1166 ,, |
| 220 yards, 40 poles, 10 chains | 1 furlong | 201·1662 metres. 0·20117 kilometre. |
| 8 furlongs, 80 chains, 1,760 yards, 5,280 feet | 1 mile | 1609·3296 metres. 1·60933 kilometres. |
| 1·1515 miles, 6080 feet | 1 Admiralty knot or nautical mile | 1·85315 kilometres. |

### English Measures of Surface.

## TABLE 16.—ORDINARY SUPERFICIAL MEASUREMENT.

| | | |
|---|---|---|
| 1 square inch | | 645·15 square millimetres. 6·4515 square centimetres. |
| 144 square inches, 183·35 circular inches | 1 square foot | ·0929 square metre. |
| 9 square feet | 1 square yard | ·8361 square metre. |
| 100 square feet (for roofing and flooring) | 1 square | 9·2901 square metres. |
| $30\frac{1}{4}$ square yards | 1 square pole, rod, or perch | 25·292 square metres. |
| 40 square poles | 1 rood | 1011·696 square metres. 10·1170 ares. |
| 4 roods, 4840 square yards | 1 acre* | 4046·782 square metres. 40·4678 ares. ·4047 hectares. |
| 640 acres | 1 square mile | 258·9894 hectares. |

The side of a square acre is equal to 69·57 lineal yards.

## English Measures of Volume and Capacity.

TABLE 17.—SOLID OR CUBIC MEASURE.

| | | |
|---|---|---|
| 1 cubic inch | | 16·387 cubic centimetres. |
| 1728 cubic inches<br>2200·15 cylindrical inches<br>3300·23 spherical inches<br>6600·45 conical inches | 1 cubic foot | 28·3153 cubic decimetres.<br>·028315 cubic metre. |
| 27 cubic feet | 1 cubic yard | ·764513 cubic metre. |
| 1·308 cubic yard<br>31·3156 cubic feet | | 1 cubic metre. |

TABLE 18.—DRY MEASURE.

| | | |
|---|---|---|
| | 1 pint | ·5679 litre. |
| 2 pints | 1 quart | 1·1359 litres. |
| 4 quarts (277·274 cubic inches) | 1 gallon | 4·5435 litres. |
| 2 gallons | 1 peck | 9·0869 litres. |
| 4 pecks (1·28366 cubic feet) | 1 bushel | 36·3477 litres. |
| 8 bushels | 1 quarter | 290·782 litres. |
| 4 quarters (41·077 cubic feet) | 1 chaldron | 1·1631 cubic metres. |
| 5 quarters | 1 load, or way | 1·4539 cubic metres. |
| 2 loads | 1 last | 2·9078 cubic metres. |

## Builders' Measurement.

TABLE 19.—LINEAL MEASURE.

| | |
|---|---|
| 12 inches | 1 foot. |
| 3 feet | 1 yard. |
| 16½ feet | 1 rod. |

The rod of 16½ feet lineal is used for measuring park-fencing. Rubble-walling, in some parts of England, is measured by the rod of 16½ feet, by 1 foot high; and the various thicknesses are stated.

TABLE 20.—SUPERFICIAL MEASURE.

| | |
|---|---|
| 1 part | 1 square inch. |
| 12 parts | 1 inch (12 square inches). |
| 12 inches | 1 foot. |
| 9 feet | 1 yard. |
| 100 feet | 1 square. |
| 272¼ feet | 1 rod. |

Brickwork generally is measured by the rod of 272 feet superficial (not 272¼ feet) reduced to 1½ bricks in thickness.

But, for engineering works, it is measured by the cubic yard of 27 cubic feet.

Flooring, slating, and tiling, are measured by the square.

Paving, painting, plastering, &c., are measured by the yard.

TABLE 21.—CUBIC MEASURE.

| | |
|---|---|
| 1 third . . . . . | 1 cubic inch. |
| 12 thirds . . . . . | 1 part (12 cubic inches). |
| 12 parts . . . . . | 1 inch (144 cubic inches). |
| 12 inches . . . . . | 1 foot (1728 cubic inches). |
| 27 feet . . . . . | 1 yard. |

Excavation, concrete, &c., are measured by the cubic yard.

Masonry, square-sided timber, &c., are measured by the cubic foot.

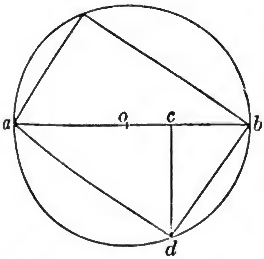



FIG. 16.—To find Strongest Section of Round Tree.

**Timber.**

The inscribed square in the section of a round tree gives the maximum of sectional area, but not the maximum of transverse strength. To find the strongest section, draw a diameter *a b*; from the centre *o* set off *o c*, one-third of the radius *o b*, and draw the perpendicular *c d*. Draw *d b* and *d a*, and complete the parallelogram. The area of the parallelogram is 6 per cent. less than that of the square section; but it is 9 per cent. stronger.

TABLE 22.—LIQUID MEASURE.

| | | |
|---|---|---|
| 8·665 cubic inches . | 1 gill or quartern . | ·1420 litre. |
| 4 gills . . . . . | 1 pint . . . . | ·5679 litre. |
| 2 pints . . . . . | 1 quart . . . . | 1·1359 litres. |
| 4 pints . . . . . | 1 pottle . . . . | 2·2718 litres. |
| 8 pints / 4 quarts } (277·274 cubic inches) | 1 gallon . . . . | 4·5435 litres. |
| 6·2355 gallons . . . | 1 cubic foot. | |
| 168·3765 gallons . . | 1 cubic yard. | |
| 220·09 gallons . . . . . . . . . | | 1 cubic metre. |

TABLE 23.—OLD WINE AND SPIRIT MEASURE.

| | | Imperial Gallons. |
|---|---|---|
| 4 gills or quarterns . . | 1 pint. | |
| 2 pints . . . . . | 1 quart. | |
| 4 quarts (231·06 cubic inches) | 1 gallon = | ·8333, or $\frac{5}{6}$. |

| | | | Imperial gallons. |
|---|---|---|---|
| $31\frac{1}{2}$ gallons | 1 barrel | = | 26·25. |
| 63 gallons, 2 barrels | 1 hogshead | = | 52·5. |
| 84 gallons | 1 puncheon | = | 70. |
| 126 gallons | 1 pipe or butt | = | 105. |
| 2 pipes | 1 tun | = | 210. |

Wines, spirits, oils, &c., are measured by this scale; but the contents of casks are reckoned in imperial gallons when sold.

### TABLE 24.—APOTHECARIES' FLUID MEASURE (ENGLISH).

| | |
|---|---|
| 60 minims (♏) | 1 fluid drachm ($f$ ʒ). |
| 8 drachms (water 1·732 cubic inches, $437\frac{1}{2}$ grains) | 1 fluid ounce ($f$ ℥). |
| 20 ounces | 1 pint ($o$). |
| 80 pints (water, 70,000 grains) | 1 gallon (gall.) |
| 4 drachms | 1 tablespoonful. |
| 2 ounces (water, 875 grains) | 1 wineglassful. |
| 3 ounces | 1 teacupful. |

### TABLE 25.—AVOIRDUPOIS WEIGHT.

| | | |
|---|---|---|
| 1 grain | | ·0648 gramme. |
| 27·344 grains | 1 drachm | 1·7718 grammes. |
| 16 drachms, $437\frac{1}{2}$ grains | 1 ounce | 28·3495 grammes. |
| 16 ounces, 7000 grains | 1 pound | 453·5926 grammes. ·45359$_3$ kilogrammes. |
| 14 pounds | 1 stone | 6·3503 kilogrammes. |
| 28 pounds | 1 quarter | 12·7006 kilogrammes. |
| 4 quarters, 112 pounds | 1 hundredweight | 50·8024 kilogrammes. |
| 20 hundredweights, 2240 pounds | 1 ton | 1016·048 kilogrammes. 1·01605 metric ton. |

### TABLE 26.—TROY WEIGHT.

| | | |
|---|---|---|
| 24 grains | 1 pennyweight | 1·5552 grammes. |
| 20 pennyweights, 480 grains | 1 troy ounce | 31·1035 grammes. |
| 12 troy ounces, 5760 grains | 1 troy pound | 373·2419 grammes. ·37324 kilogramme. |
| 25 pounds | 1 troy quarter | 9·3310 kilogrammes. |
| 4 quarters, 100 pounds | 1 troy hundredweight | 37·3242 kilogrammes. |

### Table 27.—Coal Weight (English).

| | | |
|---|---|---|
| 14 pounds | 1 stone | 6·3503 kilogrammes. |
| 88 pounds | 1 bushel | |
| 1 sack of 112 pounds | 1 hundredweight | 50·8024 kilogrammes. |
| 20 hundredweights | 1 ton | 1·01605 metric ton. |
| 26½ hundredweights | 1 chaldron (London) | 1·3462 metric ton. |
| 53 hundredweights | 1 chaldron (Newcastle) | 2·6924 metric tons. |

*Sundry bushels of coal.*—Cornish, 90 or 94 pounds; heaped, 101 pounds; Welsh, 93 pounds; Newcastle, 80 or 84 pounds; London, 80 or 84 pounds.

The "colliery ton" is 21 cwt. of 120 lbs. each.

### Table 28.—Hay and Straw Weight (English).

| | |
|---|---|
| 1 truss of straw | 36 pounds. |
| 1 load of straw | 11 hundredweights, 64 pounds. |
| 1 truss of old hay | 56 pounds. |
| 1 load of old hay | 18 hundredweights. |
| 1 truss of new hay | 60 pounds. |
| 1 load of new hay | 19 hundredweights, 32 pounds. |
| 1 cubic yard of compact old hay | 15 stones. |

Loose hay, 5 pounds per cubic foot; ordinarily pressed, as in a stack, 8 pounds; close pressed, as in a bale, 12 to 14 pounds; ordinarily pressed, as in a waggon-load, from 450 to 500 cubic feet weigh 1 ton.—*Haswell.*

### Table 29.—Corn and Flour Weight (English).

| | | |
|---|---|---|
| 1 peck, or stone, of flour | | 14 pounds |
| 10 pecks | 1 boll | 140 „ |
| 2 bolls | 1 sack | 280 „ |
| 14 pecks | 1 barrel | 196 „ |
| 1 bushel of wheat | | 60 „ |
| 1 bushel of barley | | 47 „ |
| 1 bushel of oats | | 40 „ |
| 80 bushels of corn | | 1 last. |

Six bushels of wheat should yield one sack of flour.

### Table 30.—Timber Measures for Building Purposes (English).

| | |
|---|---|
| Load of timber, unhewn or rough | 40 cubic feet. |
| Load, hewn or squared | 50 cubic feet, reckoned to weigh 20 cwt. |

| | |
|---|---|
| Stack of wood | 108 cubic feet. |
| Cord of wood | 128 ,, |

(In dockyards, 40 cubic feet of hewn timber are reckoned to weigh 20 cwt.; 50 cubic feet is a load.)

| | |
|---|---|
| 100 superficial feet of boarding or flooring | 1 square. |
| Hundred of deals | 120 deals. |
| Load of 1-inch plank | 600 square feet. |
| Load of $1\frac{1}{2}$-inch plank | 400 ,, |
| Load of 2-inch | 300 ,, |
| Load of $2\frac{1}{2}$-inch | 240 ,, |
| Load of 3-inch | 200 ,, |
| Load of $3\frac{1}{2}$-inch | 170 ,, |
| Load of 4-inch | 150 ,, |
| Planks, section | 11 by 3 inches. |
| Deals, section | 9 by 3 ,, |
| Battens, section | 7 by $2\frac{1}{2}$ ,, |

A reduced deal is $1\frac{1}{2}$ inches thick, 11 inches wide, and 12 feet long.

| | |
|---|---|
| Bundle of 4 feet oak-heart laths | 120 laths. |
| Load of ,, ,, | $37\frac{1}{2}$ bundles. |
| Bundle of 5 feet oak-heart laths | 100 laths. |
| Load of ,, ,, | 30 bundles. |

*Sundry Building Materials.*

| | |
|---|---|
| Load of statute bricks | 500. |
| Load of plain tiles | 1000. |
| Load of lime | 32 bushels. |
| Load of sand | 36 ,, |
| Hundred of lime | 35 ,, |
| Hundred of nails, or tacks | 120. |
| Thousand of nails, or tacks | 1200. |
| Fodder of lead | $19\frac{1}{2}$ cwt. |
| Sheet lead | 6 to 10 pounds per sq. ft. |
| Hundred of lead | 112 pounds. |
| Table of glass | 5 feet. |
| Case of glass | 45 tables. |
| Case of glass | (Newcastle and Normandy glass, 25 tables.) |
| Stone of glass | 5 pounds. |
| Seam of glass | 24 stone. |

TABLE 31.—ENGLISH BRICKWORK MEASURES (Mackrow).

| | ins. ins. ins. | Weight. |
|---|---|---|
| London stock bricks | $8\frac{3}{4} \times 4\frac{1}{4} \times 2\frac{3}{4}$ | 6·81 lbs. |
| Red kiln | $8\frac{3}{4} \times 4\frac{1}{4} \times 2\frac{3}{4}$ | 7·00 ,, |
| Welsh fire | $9 \times 4\frac{1}{2} \times 2\frac{3}{4}$ | 7·84 ,, |

| | ins. ins. ins. | Weight. |
|---|---|---|
| Paving | $9 \times 4\frac{1}{2} \times 1\frac{3}{4}$ | 5·00 lbs. |
| Square tiles | $9\frac{3}{4} \times 9\frac{3}{4} \times 1$ | 5·70 „ |
| do. | $6 \times 6 \times 1$ | 2·16 „ |

A rod of brickwork is,—

$16\frac{1}{2}$ feet × $16\frac{1}{2}$ feet × $1\frac{1}{2}$ bricks thick ;
306 cubic feet, or $11\frac{1}{3}$ cubic yards ;
272 superficial feet $1\frac{1}{2}$ bricks thick ;
4352 stock bricks, 4 courses 1 foot high.

Bricks absorb about $\frac{1}{16}$th of their weight of water.

A rod of brick-work requires about 3 cubic yards of mortar, or $1\frac{1}{2}$ cubic yards of chalk lime and 3 loads of sand, or 1 cubic yard of stone lime and $3\frac{1}{2}$ loads of sand, or 36 bushels of cement and an equal quantity of sand.

A load of mortar or of sand is 1 cubic yard.

A bag of cement is 3 bushels.

A sack of cement is 5 bushels.

A load of mortar requires about 9 bushels of lime and 1 cubic yard or load of sand.

One load of bricks, 500 bricks.

330 stock bricks weigh 1 ton.

1000 bricks loosely stacked occupy about 72 cubic feet (14 bricks per cubic foot).

1000 bricks closely stacked occupy about 56 cubic feet (18 bricks per cubic foot).

Mortar is composed of 1 part of lime to 3 or $3\frac{1}{2}$ parts of sharp sand.

Concrete is composed of 1 part of lime, 4 parts of gravel, and 2 parts of sand.

Cement is composed of 1 part of Portland cement to 3 parts of sand. Or cement alone may be used.

TABLE 32.—TONNAGE OF SHIPS (ENGLISH).

| | | |
|---|---|---|
| 1 ton, displacement of a ship | 35 | cubic feet. |
| 1 ton, freight by measurement | 40 | „ |
| 1 ton, registered internal capacity of a ship | 100 | „ |
| 1 ton, shipbuilders' old measurement | 94 | „ |

**Wire-Gauges.**

The oldest and best-known Birmingham Wire-Gauge is that of which the numbers were carefully measured by Mr. Holtzapffel, and published by him in 1847. He gives 40 measurements ranging from ·454 inch to ·004 inch, as recorded in Table 33. It was accepted by the Standards Depart-

ment of the Board of Trade. Although there are only 40 marks in the table, there were 60 different sizes of wire made, for which intermediate sizes were added to the gauge.

TABLE 33.—BIRMINGHAM WIRE-GAUGE.

(Stubs.)

| Mark. | Size. | Mark. | Size. | Mark. | Size. | Mark. | Size. |
|---|---|---|---|---|---|---|---|
| No. | Inch. | No. | Inch. | No. | Inch. | No. | Inch. |
| 4/0 | ·454 | 7 | ·180 | 17 | ·058 | 27 | ·016 |
| 3/0 | ·425 | 8 | ·165 | 18 | ·049 | 28 | ·014 |
| 2/0 | ·380 | 9 | ·148 | 19 | ·042 | 29 | ·013 |
| 0 | ·340 | 10 | ·134 | 20 | ·035 | 30 | ·012 |
| 1 | ·300 | 11 | ·120 | 21 | ·032 | 31 | ·010 |
| 2 | ·284 | 12 | ·109 | 22 | ·028 | 32 | ·009 |
| 3 | ·259 | 13 | ·095 | 23 | ·025 | 33 | ·008 |
| 4 | ·238 | 14 | ·083 | 24 | ·022 | 34 | ·007 |
| 5 | ·220 | 15 | ·072 | 25 | ·020 | 35 | ·005 |
| 6 | ·203 | 16 | ·065 | 26 | ·018 | 36 | ·004 |

The wire-gauge that has been in common use by the sheet-rollers of South Staffordshire, ranges from $\frac{5}{16}$ inch to $\frac{1}{80}$ inch in thickness, according to the following Table :—

TABLE 34.—BIRMINGHAM WIRE-GAUGE.

*For Iron Sheets chiefly.*

| No. | Size. | No. | Size. | No. | Size. | No. | Size. |
|---|---|---|---|---|---|---|---|
| | Inch. | | Inch. | | Inch. | | Inch. |
| 1 | ·3125 ($^5/_{16}$) | 9 | ·15625 | 17 | ·05625 | 25 | ·02344 |
| 2 | ·28125 | 10 | ·140625 | 18 | ·05 ($^1/_{20}$) | 26 | ·021875 |
| 3 | ·25 ($^1/_4$) | 11 | ·125 ($^1/_8$) | 19 | ·04375 | 27 | ·020312 |
| 4 | ·234375 | 12 | ·1125 | 20 | ·0375 | 28 | ·01875 |
| 5 | ·21875 | 13 | ·10 ($^1/_{10}$) | 21 | ·034375 | 29 | ·01719 |
| 6 | ·203125 | 14 | ·0875 | 22 | ·03125 ($^1/_{32}$) | 30 | ·015625 |
| 7 | ·1875 ($^3/_{16}$) | 15 | ·075 | 23 | ·028125 | 31 | ·01406 |
| 8 | ·171875 | 16 | ·0625 ($^1/_{16}$) | 24 | ·025 ($^1/_{40}$) | 32 | ·0125 ($^1/_{80}$) |

Sir Joseph Whitworth, in 1857, promulgated his Standard Wire-Gauge, ranging from half an inch to one-thousandth of an inch, and comprising 62 measurements, given in Table 35. The sizes are designated or marked by their respective values. The Whitworth gauge has been in general use.

TABLE 35.—WHITWORTH WIRE-GAUGE, 1857.

| Mark. | Size. | Mark. | Size. | Mark. | Size. | Mark. | Size. |
|---|---|---|---|---|---|---|---|
| No. | Inch. | No. | Inch. | No. | Inch. | No. | Inch. |
| 1 | ·001 | 17 | ·017 | 55 | ·055 | 200 | ·200 |
| 2 | ·002 | 18 | ·018 | 60 | ·060 | 220 | ·220 |
| 3 | ·003 | 19 | ·019 | 65 | ·065 | 240 | ·240 |
| 4 | ·004 | 20 | ·020 | 70 | ·070 | 260 | ·260 |
| 5 | ·005 | 22 | ·022 | 75 | ·075 | 280 | ·280 |
| 6 | ·006 | 24 | ·024 | 80 | ·080 | 300 | ·300 |
| 7 | ·007 | 26 | ·026 | 85 | ·085 | 325 | ·325 |
| 8 | ·008 | 28 | ·028 | 90 | ·090 | 350 | ·350 |
| 9 | ·009 | 30 | ·030 | 95 | ·095 | 375 | ·375 |
| 10 | ·010 | 32 | ·032 | 100 | ·100 | 400 | ·400 |
| 11 | ·011 | 34 | ·034 | 110 | ·110 | 425 | ·425 |
| 12 | ·012 | 36 | ·036 | 120 | ·120 | 450 | ·450 |
| 13 | ·013 | 38 | ·038 | 135 | ·135 | 475 | ·475 |
| 14 | ·014 | 40 | ·040 | 150 | ·150 | 500 | ·500 |
| 15 | ·015 | 45 | ·045 | 165 | ·165 | | |
| 16 | ·016 | 50 | ·050 | 180 | ·180 | | |

TABLE 36.—IMPERIAL STANDARD WIRE-GAUGE.

| Descriptive Number. | Equivalents in Parts of an Inch. | Metric Equivalents. | Sectional Area of Wire. | |
|---|---|---|---|---|
| No. | Inch. | Millimetres. | Square Inch. | Square Millimetres. |
| 7/0 | ·500 | 12·700 | ·1963 | 126·67 |
| 6/0 | ·464 | 11·785 | ·1691 | 109·09 |
| 5/0 | ·432 | 10·973 | ·1466 | 94·56 |
| 4/0 | ·400 | 10·160 | ·1257 | 81·07 |
| 3/0 | ·372 | 9·449 | ·1087 | 70·12 |
| 2/0 | ·348 | 8·839 | ·0951 | 61·36 |
| 0 | ·324 | 8·229 | ·0824 | 53·19 |
| 1 | ·300 | 7·620 | ·0707 | 45·60 |
| 2 | ·276 | 7·010 | ·0598 | 38·58 |
| 3 | ·252 | 6·401 | ·0499 | 32·18 |
| 4 | ·232 | 5·893 | ·0423 | 27·27 |
| 5 | ·212 | 5·385 | ·0353 | 22·77 |
| 6 | ·192 | 4·877 | ·0289 | 18·68 |
| 7 | ·176 | 4·470 | ·0243 | 15·70 |
| 8 | ·160 | 4·064 | ·0201 | 12·97 |
| 9 | ·144 | 3·658 | ·0163 | 10·51 |

TABLE 36.—IMPERIAL STANDARD WIRE-GAUGE (*continued*).

| Descriptive Number. | Equivalents in Parts of an Inch. | Metric Equivalents. | Sectional Area of Wire. | |
|---|---|---|---|---|
| No. | Inch. | Millimetres. | Square Inch. | Square Millimetres. |
| 10 | ·128 | 3·251 | ·0129 | 8·30 |
| 11 | ·116 | 2·946 | ·0106 | 6·82 |
| 12 | ·104 | 2·642 | ·00849 | 5·48 |
| 13 | ·092 | 2·337 | ·00665 | 4·29 |
| 14 | ·080 | 2·032 | ·00503 | 3·24 |
| 15 | ·072 | 1·829 | ·00407 | 2·63 |
| 16 | ·064 | 1·626 | ·00322 | 2·07 |
| 17 | ·056 | 1·422 | ·00246 | 1·59 |
| 18 | ·048 | 1·219 | ·00181 | 1·17 |
| 19 | ·040 | 1·016 | ·00126 | ·811 |
| 20 | ·036 | ·914 | ·00102 | ·657 |
| 21 | ·032 | ·813 | ·000804 | ·519 |
| 22 | ·028 | ·711 | ·000616 | ·397 |
| 23 | ·024 | ·610 | ·000452 | ·292 |
| 24 | ·022 | ·559 | ·000380 | ·245 |
| 25 | ·020 | ·508 | ·000314 | ·203 |
| 26 | ·018 | ·457 | ·000254 | ·164 |
| 27 | ·0164 | ·4166 | ·000211 | ·136 |
| 28 | ·0148 | ·3759 | ·000173 | ·111 |
| 29 | ·0136 | ·3454 | ·000145 | ·0937 |
| 30 | ·0124 | ·3150 | ·000121 | ·0779 |
| 31 | ·0116 | ·2946 | ·000106 | ·0682 |
| 32 | ·0108 | ·2743 | ·0000916 | ·0591 |
| 33 | ·0100 | ·2540 | ·0000785 | ·0507 |
| 34 | ·0092 | ·2337 | ·0000665 | ·0429 |
| 35 | ·0084 | ·2134 | ·0000554 | ·0357 |
| 36 | ·0076 | ·1930 | ·0000454 | ·0293 |
| 37 | ·0068 | ·1727 | ·0000363 | ·0234 |
| 38 | ·0060 | ·1524 | ·0000283 | ·0182 |
| 39 | ·0052 | ·1321 | ·0000212 | ·0137 |
| 40 | ·0048 | ·1219 | ·0000181 | ·0117 |
| 41 | ·0044 | ·1118 | ·0000152 | ·00982 |
| 42 | ·0040 | ·1016 | ·0000126 | ·00811 |
| 43 | ·0036 | ·0914 | ·0000102 | ·00656 |
| 44 | ·0032 | ·0813 | ·00000804 | ·00519 |
| 45 | ·0028 | ·0711 | ·00000616 | ·00397 |
| 46 | ·0024 | ·0610 | ·00000452 | ·00292 |
| 47 | ·0020 | ·0508 | ·00000314 | ·00203 |
| 48 | ·0016 | ·0406 | ·00000201 | ·00129 |
| 49 | ·0012 | ·0305 | ·00000113 | ·00073 |
| 50 | ·0010 | ·0254 | ·000000785 | ·00051 |

### TABLE 37.—WARRINGTON WIRE GAUGE.
(Rylands Brothers.)
*(Rarely used now.)*

| Mark. | Size. | Mark. | Size. | Mark. | Size. |
|---|---|---|---|---|---|
| No. | Inch. | No. | Inch. | No. | Inch. |
| 7/0 | $\frac{1}{2}$ | 4 | ·229 | 13 | ·090 |
| 6/0 | $\frac{15}{32}$ | 5 | ·209 | 14 | ·079 |
| 5/0 | $\frac{7}{16}$ | 6 | ·191 | 15 | ·069 |
| 4/0 | $\frac{13}{32}$ | 7 | ·174 | 16 | ·0625 or $\frac{1}{16}$ |
| 3/0 | $\frac{3}{8}$ | 8 | ·159 | 17 | ·053 |
| 2/0 | $\frac{11}{32}$ | 9 | ·146 | 18 | ·047 |
| 0 | ·326 | 10 | ·135 | 19 | ·041 |
| 1 | ·300 | $10\frac{1}{2}$ | ·125 or $\frac{1}{8}$ | 20 | ·036 |
| 2 | ·274 | 11 | ·117 | 21 | ·0315 or $\frac{1}{32}$ |
| 3 | ·250 or $\frac{1}{4}$ | 12 | ·100 or $\frac{1}{10}$ | 22 | ·028 |

### TABLE 38.—HOLTZAPFFEL'S LANCASHIRE GAUGE.
*(For Round Steel Wire and Pinion Wire.)*

| Mark. | Size. | Mark. | Size. | Mark. | Size. | Mark. | Size. | Mark. | Size. |
|---|---|---|---|---|---|---|---|---|---|
| No. | Inch. | No. | Inch. | No. | Inch. | No. | Inch. | No. | Inch. |
| 80 | ·013 | 57 | ·042 | 34 | ·109 | 11 | ·189 | M | ·295 |
| 79 | ·014 | 56 | ·044 | 33 | ·111 | 10 | ·190 | N | ·302 |
| 78 | ·015 | 55 | ·050 | 32 | ·115 | 9 | ·191 | O | ·316 |
| 77 | ·016 | 54 | ·055 | 31 | ·118 | 8 | ·192 | P | ·323 |
| 76 | ·018 | 53 | ·058 | 30 | ·125 | 7 | ·195 | Q | ·332 |
| 75 | ·019 | 52 | ·060 | 29 | ·134 | 6 | ·198 | R | ·339 |
| 74 | ·022 | 51 | ·064 | 28 | ·138 | 5 | ·201 | S | ·348 |
| 73 | ·023 | 50 | ·067 | 27 | ·141 | 4 | ·204 | T | ·358 |
| 72 | ·024 | 49 | ·070 | 26 | ·143 | 3 | ·209 | U | ·368 |
| 71 | ·026 | 48 | ·073 | 25 | ·146 | 2 | ·219 | V | ·377 |
| 70 | ·027 | 47 | ·076 | 24 | ·148 | 1 | ·227 | W | ·386 |
| 69 | ·029 | 46 | ·078 | 23 | ·150 | A | ·234 | X | ·397 |
| 68 | ·030 | 45 | ·080 | 22 | ·152 | B | ·238 | Y | ·404 |
| 67 | ·031 | 44 | ·084 | 21 | ·157 | C | ·242 | Z | ·413 |
| 66 | ·032 | 43 | ·086 | 20 | ·160 | D | ·246 | A1 | ·420 |
| 65 | ·033 | 42 | ·091 | 19 | ·164 | E | ·250 | B1 | ·431 |
| 64 | ·034 | 41 | ·095 | 18 | ·167 | F | ·257 | C1 | ·443 |
| 63 | ·035 | 40 | ·096 | 17 | ·169 | G | ·261 | D1 | ·452 |
| 62 | ·036 | 39 | ·098 | 16 | ·174 | H | ·266 | E1 | ·462 |
| 61 | ·038 | 38 | ·100 | 15 | ·175 | I | ·272 | F1 | ·475 |
| 60 | ·039 | 37 | ·102 | 14 | ·177 | Kj | ·277 | G1 | ·484 |
| 59 | ·040 | 36 | ·105 | 13 | ·180 | K | ·281 | H1 | ·494 |
| 58 | ·041 | 35 | ·107 | 12 | ·185 | L | ·290 | | |

The Imperial Standard Wire-Gauge was legally established March 1, 1884. It is given in Table 36.

The Warrington Wire-Gauge, formerly practised by Rylands Brothers, is given in Table 37. It is rarely used now.

The Lancashire Gauge, Table 38, arranged by Holtzapffel, is employed for the manufacture of bright steel wire in Lancashire, and steel pinion-wire used in clocks and watches. The larger sizes, distinguished by letters, form the *Letter-Gauge*.

There are also the Needle-gauge, for needle-wire, and the Music Wire-gauge, for the strings of pianofortes.

TABLE 39.—ADMIRALTY KNOTS AND STATUTE MILES.

| Knots. | Miles. | Knots. | Miles. | Knots. | Miles. | Knots. | Miles. |
|---|---|---|---|---|---|---|---|
| ·10 | ·1152 | 5·50 | 6·3333 | 12·25 | 14·1061 | 18·75 | 21·5909 |
| ·20 | ·2303 | 5·75 | 6·6212 | 12·50 | 14·3939 | 19·00 | 21·8788 |
| ·30 | ·3455 | 6·00 | 6·9091 | 12·75 | 14·6818 | 19·25 | 22·1667 |
| ·40 | ·4606 | 6·25 | 7·1970 | 13·00 | 14·9697 | 19·50 | 22·4545 |
| ·50 | ·5758 | 6·50 | 7·4848 | 13·25 | 15·2576 | 19·75 | 22·7424 |
| ·60 | ·6909 | 6·75 | 7·7727 | 13·50 | 15·5455 | 20·00 | 23·0303 |
| ·70 | ·8061 | 7·00 | 8·0606 | 13·75 | 15·8333 | 20·50 | 23·6061 |
| ·80 | ·9212 | 7·25 | 8·3485 | 14·00 | 16·1212 | 21·00 | 24·1818 |
| ·90 | 1·0363 | 7·50 | 8·6364 | 14·25 | 16·4091 | 21·50 | 24·7576 |
| 1·00 | 1·1515 | 7·75 | 8·9242 | 14·50 | 16·6970 | 22·00 | 25·3333 |
| 1·25 | 1·4394 | 8·00 | 9·2121 | 14·75 | 16·9848 | 22·50 | 25·9091 |
| 1·50 | 1·7273 | 8·25 | 9·5000 | 15·00 | 17·2727 | 23·00 | 26·4848 |
| 1·75 | 2·0152 | 8·50 | 9·7879 | 15·25 | 17·5606 | 23·50 | 27·0606 |
| 2·00 | 2·3030 | 8·75 | 10·0758 | 15·50 | 17·8485 | 24·00 | 27·6364 |
| 2·25 | 2·5909 | 9·00 | 10·3636 | 15·75 | 18·1364 | 24·50 | 28·2121 |
| 2·50 | 2·8788 | 9·25 | 10·6515 | 16·00 | 18·4242 | 25·00 | 28·7879 |
| 2·75 | 3·1667 | 9·50 | 10·9394 | 16·25 | 18·7121 | 25·50 | 29·3636 |
| 3·00 | 3·4546 | 9·75 | 11·2273 | 16·50 | 19·0000 | 26·00 | 29·9393 |
| 3·25 | 3·7424 | 10·00 | 11·5152 | 16·75 | 19·2879 | 26·50 | 30·5151 |
| 3·50 | 4·0303 | 10·25 | 11·8030 | 17·00 | 19·5758 | 27·00 | 31·0908 |
| 3·75 | 4·3182 | 10·50 | 12·0909 | 17·25 | 19·8636 | 27·50 | 31·6668 |
| 4·00 | 4·6061 | 10·75 | 12·3788 | 17·50 | 20·1515 | 28·00 | 32·2426 |
| 4·25 | 4·8939 | 11·00 | 12·6667 | 17·75 | 20·4394 | 28·50 | 32·8183 |
| 4·50 | 5·1818 | 11·25 | 13·9545 | 18·00 | 20·7273 | 29·00 | 33·3941 |
| 4·75 | 5·4697 | 11·50 | 13·2424 | 18·25 | 21·0512 | 29·50 | 33·9698 |
| 5·00 | 5·7576 | 11·75 | 12·5303 | 18·50 | 21·3030 | 30·00 | 34·5456 |
| 5·25 | 6·0455 | 12·00 | 13·8182 | | | | |

# TABLE 40.—VULGAR FRACTIONS OF A LINEAL INCH IN DECIMAL FRACTIONS.

*Advancing by Eighths.*

| Eighths. | Fractions. | Decimals of an Inch. | Eighths. | Fractions. | Decimals of an Inch. |
|---|---|---|---|---|---|
| 1 | $\frac{1}{8}$ | ·125 | 5 | $\frac{5}{8}$ | ·625 |
| 2 | $\frac{1}{4}$ | ·25 | 6 | $\frac{3}{4}$ | ·75 |
| 3 | $\frac{3}{8}$ | ·375 | 7 | $\frac{7}{8}$ | ·875 |
| 4 | $\frac{1}{2}$ | ·5 | 8 | 1 | 1·0 |

*Advancing by Twelfths.*

| Twelfths. | Fractions. | Decimals of an Inch. | Twelfths. | Fractions. | Decimals of an Inch. |
|---|---|---|---|---|---|
| 1 | $\frac{1}{12}$ | $\cdot083\dot{3}$ | 7 | $\frac{7}{12}$ | $\cdot583\dot{3}$ |
| 2 | $\frac{1}{6}$ | $\cdot166\dot{6}$ | 8 | $\frac{2}{3}$ | $\cdot666\dot{6}$ |
| 3 | $\frac{1}{4}$ | ·25 | 9 | $\frac{3}{4}$ | ·75 |
| 4 | $\frac{1}{3}$ | $\cdot333\dot{3}$ | 10 | $\frac{5}{6}$ | $\cdot833\dot{3}$ |
| 5 | $\frac{5}{12}$ | $\cdot416\dot{6}$ | 11 | $\frac{11}{12}$ | $\cdot916\dot{6}$ |
| 6 | $\frac{1}{2}$ | ·5 | 12 | 1 | 1·0 |

*Advancing by Sixteenths.*

| Six-teenths. | Fractions. | Decimals of an Inch. | Six-teenths. | Fractions. | Decimals of an Inch. |
|---|---|---|---|---|---|
| 1 | $\frac{1}{16}$ | ·0625 | 9 | $\frac{9}{16}$ | ·5625 |
| 2 | $\frac{1}{8}$ | ·125 | 10 | $\frac{5}{8}$ | ·625 |
| 3 | $\frac{3}{16}$ | ·1875 | 11 | $\frac{11}{16}$ | ·6875 |
| 4 | $\frac{1}{4}$ | ·25 | 12 | $\frac{3}{4}$ | ·75 |
| 5 | $\frac{5}{16}$ | ·3125 | 13 | $\frac{13}{16}$ | ·8125 |
| 6 | $\frac{3}{8}$ | ·375 | 14 | $\frac{7}{8}$ | ·875 |
| 7 | $\frac{7}{16}$ | ·4375 | 15 | $\frac{15}{16}$ | ·9375 |
| 8 | $\frac{1}{2}$ | ·5 | 16 | 1 | 1·0 |

## TABLE 40.—VULGAR FRACTIONS OF A LINEAL INCH IN DECIMAL FRACTIONS (*continued*).

*Advancing by Thirty-seconds.*

| Thirty-seconds. | Fractions. | Decimals of an Inch. | Thirty-seconds. | Fractions. | Decimals of an Inch. |
|---|---|---|---|---|---|
| 1 | $\frac{1}{32}$ | ·03125 | 17 | $\frac{17}{32}$ | ·53125 |
| 2 | $\frac{1}{16}$ | ·0625 | 18 | $\frac{9}{16}$ | ·5625 |
| 3 | $\frac{3}{32}$ | ·09375 | 19 | $\frac{19}{32}$ | ·59375 |
| 4 | $\frac{1}{8}$ | ·125 | 20 | $\frac{5}{8}$ | ·625 |
| 5 | $\frac{5}{32}$ | ·15625 | 21 | $\frac{21}{32}$ | ·65625 |
| 6 | $\frac{3}{16}$ | ·1875 | 22 | $\frac{11}{16}$ | ·6875 |
| 7 | $\frac{7}{32}$ | ·21875 | 23 | $\frac{23}{32}$ | ·71875 |
| 8 | $\frac{1}{4}$ | ·25 | 24 | $\frac{3}{4}$ | ·75 |
| 9 | $\frac{9}{32}$ | ·28125 | 25 | $\frac{25}{32}$ | ·78125 |
| 10 | $\frac{5}{16}$ | ·3125 | 26 | $\frac{13}{16}$ | ·8125 |
| 11 | $\frac{11}{32}$ | ·34375 | 27 | $\frac{27}{32}$ | ·84375 |
| 12 | $\frac{3}{8}$ | ·375 | 28 | $\frac{7}{8}$ | ·875 |
| 13 | $\frac{13}{32}$ | ·40625 | 29 | $\frac{29}{32}$ | ·90625 |
| 14 | $\frac{7}{16}$ | ·4375 | 30 | $\frac{15}{16}$ | ·9375 |
| 15 | $\frac{15}{32}$ | ·46875 | 31 | $\frac{31}{32}$ | ·96875 |
| 16 | $\frac{1}{2}$ | ·5 | 32 | 1 | 1·0 |

*Advancing by odd Sixty-fourths.*

| Sixty-fourths. | | Decimals of an Inch. | Sixty-fourths. | | Decimals of an Inch. |
|---|---|---|---|---|---|
| 1 | | ·015625 | 35 | | ·546875 |
| 3 | | ·031250 | 37 | | ·578125 |
| 5 | | ·078125 | 39 | | ·609375 |
| 7 | | ·109375 | 41 | | ·640625 |
| 9 | | ·140625 | 43 | | ·671875 |
| 11 | | ·171875 | 45 | | ·703125 |
| 13 | | ·203125 | 47 | | ·734375 |
| 15 | | ·234375 | 49 | | ·765625 |
| 17 | | ·265625 | 51 | | ·796875 |
| 19 | | ·296875 | 53 | | ·828125 |
| 21 | | ·328125 | 55 | | ·859375 |
| 23 | | ·359375 | 57 | | ·890625 |
| 25 | | ·390625 | 59 | | ·921875 |
| 27 | | ·421875 | 61 | | ·953125 |
| 29 | | ·453125 | 63 | | ·984375 |
| 31 | | ·484375 | 64 | | 1·0 |
| 33 | | ·515625 | | | |

## TABLE 41.—LINEAL INCHES IN DECIMAL FRACTIONS OF A LINEAL FOOT.

| Lineal Inches. | Lineal Foot. | Lineal Inches. | Lineal Foot. | Lineal Inches. | Lineal Foot. |
|---|---|---|---|---|---|
| $\frac{1}{64}$ | ·001302083̇ | $1\frac{7}{8}$ | ·15625 | $6\frac{1}{2}$ | ·5416̇ |
| $\frac{1}{32}$ | ·00260416̇ | 2 | ·1666̇ | $6\frac{3}{4}$ | ·5625 |
| $\frac{1}{16}$ | ·0052083̇ | $2\frac{1}{8}$ | ·177083̇ | 7 | ·5833̇ |
| $\frac{1}{8}$ | ·010416̇ | $2\frac{1}{4}$ | ·1875 | $7\frac{1}{4}$ | ·60416̇ |
| $\frac{3}{16}$ | ·015625 | $2\frac{3}{8}$ | ·197916̇ | $7\frac{1}{2}$ | ·625 |
| $\frac{1}{4}$ | ·02083̇ | $2\frac{1}{2}$ | ·2083̇ | $7\frac{3}{4}$ | ·64583̇ |
| $\frac{5}{16}$ | ·0260416̇ | $2\frac{5}{8}$ | ·21875 | 8 | ·6666̇ |
| $\frac{3}{8}$ | ·03125 | $2\frac{3}{4}$ | ·22916̇ | $8\frac{1}{4}$ | ·6875 |
| $\frac{7}{16}$ | ·0364583̇ | $2\frac{7}{8}$ | ·239583̇ | $8\frac{1}{2}$ | ·7083̇ |
| $\frac{1}{2}$ | ·0416̇ | 3 | ·25 | $8\frac{3}{4}$ | ·72916̇ |
| $\frac{9}{16}$ | ·046875 | $3\frac{1}{4}$ | ·27083̇ | 9 | ·75 |
| $\frac{5}{8}$ | ·052083̇ | $3\frac{1}{2}$ | ·2916̇ | $9\frac{1}{4}$ | ·77083̇ |
| $\frac{11}{16}$ | ·0572916̇ | $3\frac{3}{4}$ | ·3125 | $9\frac{1}{2}$ | ·7916̇ |
| $\frac{3}{4}$ | ·0625 | 4 | ·3333̇ | $9\frac{3}{4}$ | ·8125 |
| $\frac{13}{16}$ | ·0677083̇ | $4\frac{1}{4}$ | ·35416̇ | 10 | ·8333̇ |
| $\frac{7}{8}$ | ·072916̇ | $4\frac{1}{2}$ | ·375 | $10\frac{1}{4}$ | ·85416̇ |
| $\frac{15}{16}$ | ·078125 | $4\frac{3}{4}$ | ·39583̇ | $10\frac{1}{2}$ | ·875 |
| 1 | ·0833̇ | 5 | ·4166̇ | $10\frac{3}{4}$ | ·89583̇ |
| $1\frac{1}{8}$ | ·09375 | $5\frac{1}{4}$ | ·4375 | 11 | ·9166̇ |
| $1\frac{1}{4}$ | ·10416̇ | $5\frac{1}{2}$ | ·4583̇ | $11\frac{1}{4}$ | ·9375 |
| $1\frac{3}{8}$ | ·114583̇ | $5\frac{3}{4}$ | ·47916̇ | $11\frac{1}{2}$ | ·9583̇ |
| $1\frac{1}{2}$ | ·125 | 6 | ·5 | $11\frac{3}{4}$ | ·97916̇ |
| $1\frac{5}{8}$ | ·135416̇ | $6\frac{1}{4}$ | ·52083̇ | 12 | 1·0000 |
| $1\frac{3}{4}$ | ·14583̇ | | | | |

TABLE 42.—SQUARE INCHES IN DECIMAL FRACTIONS OF A SQUARE FOOT.

| Square Inches. | Square Foot. | Square Inches. | Square Foot. | Square Inches. | Square Foot. | Square Inches. | Square Foot. |
|---|---|---|---|---|---|---|---|
| ·10 | ·0006944 | 24 | ·16666 | 65 | ·45138 | 105 | ·72916 |
| ·15 | ·0010416 | 25 | ·17361 | 66 | ·45833 | 106 | ·73611 |
| ·20 | ·001388 | 26 | ·18055 | 67 | ·46527 | 107 | ·74305 |
| ·25 | ·0017361 | 27 | ·18750 | 68 | ·47222 | 108 | ·75000 |
| ·30 | ·002083 | 28 | ·19444 | 69 | ·47916 | 109 | ·75694 |
| ·35 | ·0024305 | 29 | ·20138 | 70 | ·48611 | 110 | ·76388 |
| ·40 | ·002777 | 30 | ·20833 | 71 | ·49305 | 111 | ·77083 |
| ·45 | ·00311249 | 31 | ·21527 | 72 | ·50000 | 112 | ·77777 |
| ·50 | ·003472 | 32 | ·22222 | 73 | ·50694 | 113 | ·78472 |
| ·55 | ·0038194 | 33 | ·22916 | 74 | ·51388 | 114 | ·79166 |
| ·60 | ·004166 | 34 | ·23611 | 75 | ·52083 | 115 | ·79861 |
| ·65 | ·0045138 | 35 | ·24305 | 76 | ·52777 | 116 | ·80555 |
| ·70 | ·004861 | 36 | ·25000 | 77 | ·53472 | 117 | ·81249 |
| ·75 | ·0052083 | 37 | ·25694 | 78 | ·54166 | 118 | ·81944 |
| ·80 | ·005555 | 38 | ·26388 | 79 | ·54861 | 119 | ·82638 |
| ·85 | ·0059027 | 39 | ·27083 | 80 | ·55555 | 120 | ·83333 |
| ·90 | ·006250 | 40 | ·27777 | 81 | ·56249 | 121 | ·84027 |
| ·95 | ·0065972 | 41 | ·28472 | 82 | ·56944 | 122 | ·84722 |
| 1 | ·006944 | 42 | ·29166 | 83 | ·57638 | 123 | ·85416 |
| 2 | ·01388 | 43 | ·29861 | 84 | ·58333 | 124 | ·86111 |
| 3 | ·02083 | 44 | ·30555 | 85 | ·59027 | 125 | ·86805 |
| 4 | ·02777 | 45 | ·31249 | 86 | ·59722 | 126 | ·87500 |
| 5 | ·03472 | 46 | ·31944 | 87 | ·60416 | 127 | ·88194 |
| 6 | ·04166 | 47 | ·32638 | 88 | ·61111 | 128 | ·88888 |
| 7 | ·04861 | 48 | ·33333 | 89 | ·61805 | 129 | ·89583 |
| 8 | ·05555 | 49 | ·34027 | 90 | ·62500 | 130 | ·90277 |
| 9 | ·06250 | 50 | ·34722 | 91 | ·63194 | 131 | ·90972 |
| 10 | ·06944 | 51 | ·35416 | 92 | ·63888 | 132 | ·91666 |
| 11 | ·07638 | 52 | ·36111 | 93 | ·64583 | 133 | ·92361 |
| 12 | ·08333 | 53 | ·36805 | 94 | ·65277 | 134 | ·93055 |
| 13 | ·09027 | 54 | ·37500 | 95 | ·65972 | 135 | ·93750 |
| 14 | ·09722 | 55 | ·38194 | 96 | ·66666 | 136 | ·94444 |
| 15 | ·10416 | 56 | ·38888 | 97 | ·67361 | 137 | ·95138 |
| 16 | ·11111 | 57 | ·39583 | 98 | ·68055 | 138 | ·95833 |
| 17 | ·11805 | 58 | ·40277 | 99 | ·68750 | 139 | ·96527 |
| 18 | ·12500 | 59 | ·40972 | 100 | ·69444 | 140 | ·97222 |
| 19 | ·13194 | 60 | ·41666 | 101 | ·70138 | 141 | ·97916 |
| 20 | ·13888 | 61 | ·42361 | 102 | ·70833 | 142 | ·98611 |
| 21 | ·14583 | 62 | ·43055 | 103 | ·71527 | 143 | ·99305 |
| 22 | ·15277 | 63 | ·43750 | 104 | ·72222 | 144 | 1·00000 |
| 23 | ·15972 | 64 | ·44444 | | | | |

## Table 43.—Decimal Fractions of a Square Foot in Square Inches.

| Square Foot. | Square Inches. | Square Foot. | Square Inches. | Square Foot. | Square Inches. | Square Foot. | Square Inches. |
|---|---|---|---|---|---|---|---|
| ·01 | 1·44 | ·26 | 37·4 | ·51 | 73·4 | ·76 | 109·4 |
| ·02 | 2·88 | ·27 | 38·9 | ·52 | 74·9 | ·77 | 110·9 |
| ·03 | 4·32 | ·28 | 40·3 | ·53 | 76·3 | ·78 | 112·3 |
| ·04 | 5·76 | ·29 | 41·8 | ·54 | 77·8 | ·79 | 113·8 |
| ·05 | 7·20 | ·30 | 43·2 | ·55 | 79·2 | ·80 | 115·2 |
| ·06 | 8·64 | ·31 | 44·6 | ·56 | 80·6 | ·81 | 116·6 |
| ·07 | 10·1 | ·32 | 46·1 | ·57 | 82·1 | ·82 | 118·1 |
| ·08 | 11·5 | ·33 | 47·5 | ·58 | 83·5 | ·83 | 119·5 |
| ·09 | 13·0 | ·34 | 49·0 | ·59 | 85·0 | ·84 | 121·0 |
| ·10 | 14·4 | ·35 | 50·4 | ·60 | 86·4 | ·85 | 122·4 |
| ·11 | 15·8 | ·36 | 51·8 | ·61 | 87·8 | ·86 | 123·8 |
| ·12 | 17·3 | ·37 | 53·3 | ·62 | 89·3 | ·87 | 125·3 |
| ·13 | 18·7 | ·38 | 54·7 | ·63 | 90·7 | ·88 | 126·7 |
| ·14 | 20·2 | ·39 | 56·2 | ·64 | 92·2 | ·89 | 128·2 |
| ·15 | 21·6 | ·40 | 57·6 | ·65 | 93·6 | ·90 | 129·6 |
| ·16 | 23·0 | ·41 | 58·0 | ·66 | 95·0 | ·91 | 131·0 |
| ·17 | 24·5 | ·42 | 60·5 | ·67 | 96·5 | ·92 | 132·5 |
| ·18 | 25·9 | ·43 | 61·9 | ·68 | 97·9 | ·93 | 133·9 |
| ·19 | 27·4 | ·44 | 63·4 | ·69 | 99·4 | ·94 | 135·4 |
| ·20 | 28·8 | ·45 | 64·8 | ·70 | 100·8 | ·95 | 136·8 |
| ·21 | 30·2 | ·46 | 66·2 | ·71 | 102·2 | ·96 | 138·2 |
| ·22 | 31·7 | ·47 | 67·7 | ·72 | 103·7 | ·97 | 139·7 |
| ·23 | 33·1 | ·48 | 69·1 | ·73 | 105·1 | ·98 | 141·1 |
| ·24 | 34·6 | ·49 | 70·6 | ·74 | 106·6 | ·99 | 142·6 |
| ·25 | 36·0 | ·50 | 72·0 | ·75 | 108·0 | 1·00 | 144·0 |

## Table 44.—Correlative Rates of Measurement (English).

| | |
|---|---|
| 100 lbs. per cubic foot . . | ·926 ounce per cubic inch.<br>24·107 cwt. per cubic yard.<br>1·2053 tons per cubic yard. |
| 1 cwt. per cubic yard . . | 4·148 lbs. per cubic foot. |
| 1 ton per cubic yard . . | 82·963 lbs. per cubic foot. |
| 1 grain per gallon (1 in 70,000 parts, by weight, of water) . . . . | 6·2321 grains per cubic foot.<br>168·36 grains per cubic yard.<br>220·09 grains per cubic metre. |
| 1 lb. per lineal yard . . | ·7857 ton per mile. |

TABLE 44.—CORRELATIVE RATES (ENGLISH)—(*continued*).

| | |
|---|---|
| 1 lb. per square inch | 144 lbs. per square foot.<br>1296 lbs. per square yard.<br>·5786 ton per square yard.<br>2·0355 inches of mercury at 32° F.<br>2·0416 inches of mercury at 62° F.<br>2·309 feet of water at 62° F.<br>27·71 inches of water at 62° F. |
| 1 atmosphere (14·7 lbs. per square inch) | 2116·4 lbs. per square foot.<br>8·503 tons per square yard.<br>33·947 feet of water at 62° F.<br>10·347 metres of water at 62° F.<br>30 inches of mercury at 62° F. |
| 1 lb. per square foot | ·00694 lb. per square inch.<br>·1111 ounce per square inch.<br>·0804 cwt. per square yard. |
| 1 inch of water at 62° F. | ·5773 ounce per square inch.<br>·0361 lb. per square inch.<br>5·20 lbs. per square foot.<br>·0736 inch of mercury at 62° F. |
| 1 foot of water at 62° F. | ·433 lb. per square inch.<br>62·355 lbs. per square foot.<br>·883 inch of mercury at 62° F. |
| 1 inch of mercury at 62° F. | ·49 lb. per square inch.<br>70·56 lbs. per square foot.<br>1·165 feet of water at 62° F.<br>14 inches of water at 62° F. |
| 1 cubic foot per second | 2·222 cubic yards per minute.<br>133·333 cubic yards per hour. |
| 1 cubic foot per minute | 2·222 cubic yards per hour. |
| ·45 cubic foot per minute | 1 cubic yard per hour. |
| 1 cubic inch per second | 2·083 cubic feet per hour.<br>12·984 gallons per hour. |
| 1 mile per hour | 1·467 feet per second.<br>88 feet per minute. |
| 1 foot per second | ·682 mile per hour. |
| 1 foot per minute | ·01136 mile per hour.<br>·20 inch per second. |
| 1 inch per second | 5 feet per minute. |

TABLE 45.—WATER.

| | |
|---|---|
| 1 Imperial gallon . . . | 277·274 cubic inches. |
| | ·1604 cubic foot. |
| | 10 pounds of water at 62° F. |
| | 70,000 grains of water at 62° F. |
| | 1·20 U.S. gallons. |
| | 4·544 litres. |
| 1 U. S. gallon . . . | 231 cubic inches. |
| | ·1337 cubic foot. |
| | 8·333 pounds of water at 62° F. |
| | ·8333 imperial gallon ($\frac{5}{6}$ths). |
| | 3·786 litres. |
| 1 cubic inch of water at 62° F. . . . . . | ·03608 pound. |
| | ·5773 ounce. |
| | 252·6 grains. |
| | ·003607 imperial gallon. |
| | ·004326 U.S. gallon. |
| | ·01638 litre. |
| 1 cubic foot of water at 62° F. | 62·355 pounds. |
| | 997·68 ounces (about 1000). |
| | ·557 cwt. |
| | ·0278 ton. |
| | 6·2355 imperial gallons. |
| | 49·884 imperial pints (about 50). |
| | 7·4805 U.S. gallons. |
| | 28·315 litres. |
| | ·02832 cubic metre. |
| 1 cylindrical inch of water at 62° F. . . . . . | ·02833 pound. |
| | ·4533 ounce. |
| | ·7854 cubic inch. |
| 1 cylindrical foot of water at 62° F. . . . . . | 48·973 pounds (about 50). |
| | 783·57 ounces. |
| | ·437 cwt. |
| | ·0219 ton. |
| | 4·8973 imperial gallons. |
| | 5·8758 U.S. gallons. |
| | 22·2380 litres. |
| | ·02224 cubic metre. |
| 1 cubic yard of water . . | 1684·8 pounds. |
| | 15·043 cwt., or 15 cwt. 4·8 pounds. |
| | ·7645 cubic metre. |
| 1 litre of water . . . | 2·2046 pounds at 62° F. |
| | ·2201 imperial gallon. |
| | 1·761 imperial pint. |
| | ·2641 U.S. gallon. |
| | 61·025 cubic inches. |
| | ·0353 cubic foot. |

TABLE 45.—WATER (*continued*).

| | |
|---|---|
| 1 cubic metre of water. | 1 tonne, or 1000 kilogrammes at 39·1° F. or 4° C.<br>2204·62 pounds at 39·1° F. or 4° C.<br>2203·7 pounds at 62·4 pounds per cubic foot.<br>1 ton of 2240 pounds, nearly.<br>1 tun of 4 hogsheads or 2100 pounds, nearly.<br>220·1 imperial gallons.<br>264·2 U.S. gallons.<br>1·308 cubic yards.<br>35·3156 cubic feet.<br>1000 litres. |

The weight of fresh water is commonly assumed, in ordinary calculations, to be 62·4 pounds per cubic foot, which is the weight at 52·3° F. It is frequently taken as 62½ pounds or 1000 ounces per cubic foot.

The volumes of given weights of water, at the rate of 62·4 pounds per cubic foot, are as follows:—

| | |
|---|---|
| 1 ton | 35·90 cubic feet (about 36). |
| 1 cwt. | 1·795 „ |
| 1 pound | ·016 „<br>27·692 cubic inches. |
| 1 ounce | 1·731 „ |
| 1 tonne, at 39·1° F. or 4° C. | 35·3156 cubic feet. |
| 1 kilogramme „ „ | ·0353 „<br>61·025 cubic inches. |
| 1 tonne, at 52·3° F. (62·4 pounds per cubic foot) | 35·330 cubic feet. |

A pipe 1 yard in length holds about as many pounds of water of ordinary temperatures as the square of its diameter in inches (about two per cent. more).

A column of water at 62° F. 1 foot high, is equivalent to a pressure of ·433 pound, or 6·928 ounces per square inch of base, or to 62·355 pounds per square foot.

A column of water 1 inch high, is equivalent to a pressure of ·5773 ounce, or ·03608 pound per square inch; or to 5·196 pounds per square foot.

A column of water 100 feet high is equivalent to 43⅓ pounds per square inch; or 2·786 tons per square foot.

A column of water 1 mile deep; weighing 62·4 pounds per cubic foot, is equivalent to a pressure of about 1 ton per square inch.

1 pound per square inch is equivalent to a column of water at 62° F. 2·31 feet or 27·72 inches high.

### Sea Water.

| | |
|---|---|
| 1 cubic foot at 62° F. . . . | 64 pounds. |
| 1 cubic yard . . . . . | 15½ cwt. nearly (8 pounds less). |
| 1 cubic metre . . . . | 1 ton fully (20 pounds more). |
| 1 ton . . . . . . . | 35 cubic feet. |
| Ratio of weight of fresh water to that of sea water . . | 39 to 40, or 1 to 1·028. |

### Ice and Snow.

| | |
|---|---|
| 1 cubic foot of ice at 32° F. | 57·50 pounds. |
| 1 pound of ice " " | ·0174 cubic foot, or 30·067 cubic inches. |

Specific density of ice, ·922; that of water at 62° F. being 1.

1 cubic foot of fresh snow, according to humidity of atmosphere: 5 pounds to 12 pounds (Trautwine).

| | |
|---|---|
| 1 cubic foot of snow moistened and compacted by rain . . . | 15 pounds to 50 pounds (Trautwine). |

### TABLE 46.—AIR.

| | |
|---|---|
| 1 cubic foot, at 14·7 lbs. per square inch, or 1 atmosphere . . . . | ·080728 pound at 32° F.<br>1·29 ounce " "<br>565·1 grains " "<br>·076097 pound at 62° F.<br>1·217 ounce " "<br>532·7 grains " " |
| 1 litre, under one atmosphere . . . . | 1·293 grammes at 32° F.<br>19·955 grains " " |
| 1 pound of air at 62° F. . | 13·141 cubic feet. |

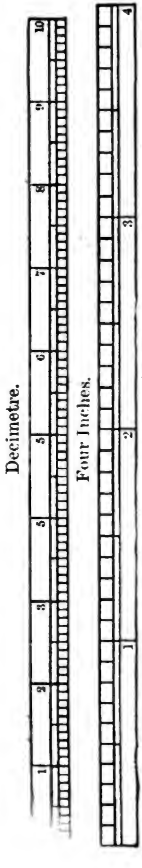
The weights of equal volumes of mercury, water and air at 62° F. under 1 atmosphere, are as 11140·56, 819·4 and 1.

| | |
|---|---|
| 1 atmosphere of pressure . | 14·7 lbs. per square inch.<br>2116·4 lbs. per square foot.<br>1·0335 kilogrammes per square centimetre.<br>29·922 inches of mercury at 32° F.<br>76 centimetres of mercury at 32° F.<br>30 inches of mercury at 62° F.<br>33·947 feet of water at 62° F.<br>10·347 metres of water at 62° F. |

TABLE 46.—AIR (*continued*).

| | |
|---|---|
| | 2·035 inches of mercury at 32° F. |
| | 51·7 millimetres " " |
| 1 lb. per square inch . . | 2·04 inches of mercury at 62° F |
| | 2·31 feet of water at 62° F. |
| | 27·72 inches " " |
| 1 ounce per square inch . | 1·732 inches " " |
| lb. per square foot . . | ·1925 inch " " |
| | ·01417 inch of mercury at 62° F. |

## French Metric Weights and Measures.




Figs. 17, 18.—French and English Measures compared.

The metre, equal to 39·37043 inches, and the kilogramme, equal to 2·20462 pounds, are the only standards of weight and measure in France. The kilogramme is defined as the weight of a cubic decimetre of distilled water at its maximum density, at 4·0° C., or 39·1° F. It is legally taken to be 2·20462125 pounds. The gramme, of which there are one thousand in the kilogramme, is the unit of weight. It is the weight of one cubic centimetre of water under the conditions above defined.

The metric unit of capacity is the litre, defined as equal to a cubic decimetre. It is equal to 0·22009 gallon.

The French metric system has been compulsorily adopted by France and Belgium in 1801; Holland in 1819; Greece in 1836; Italy and Spain, in 1859; Portugal in 1860—68; the German Empire, in 1872; Colombia, Venezuela, in 1872. The system is established in France and her Colonies, Belgium, Holland and her Colonies, Germany, Sweden, Norway, Austro-Hungary, Italy, Spain, Portugal, Turkey, Roumania, Greece, Brazil, Colombia, Uruguay, Ecuador, Peru, Chili, the Argentine Republic. It has been made legally optional in Great Britain and Ireland, the United States of North America and Canada. It is admitted in principle, or partially for customs, in British India, Russia, and Venezuela. Switzerland, in 1856, legalised the foot of three decimetres as the unit of length, with a decimal scale; with a unit of weight, the pound of 500 grammes, or half a kilogramme, with two distinct scales of multiples and parts, one decimal, the other on the old system. Denmark adopted the metric system so far as the pound of 500 grammes.

### TABLE 47.—FRENCH MEASURES OF LENGTH.

| | | Metres. | English Equivalents. |
|---|---|---|---|
| | 1 millimetre = | ·001 = | ·03937 in., or $\frac{1}{25}$ in. nearly. |
| 10 millimetres | = 1 centimetre = | ·01 = | ·3937 inch. |
| 10 centimetres | = 1 decimetre = | ·1 = | 3·93704 in., or 4 ins. nearly |
| 10 decimetres, 100 centimetres, 1000 millimetres | = 1 METRE = | 1 = | 39·3704 ins. / 3·2809 feet. |
| 10 metres | = 1 decametre = | 10 = | 32·8087 feet. |
| 10 decametres | = 1 hectometre = | 100 = | 328·0869 feet. / 109·3623 yds. |
| 10 hectometres | = 1 KILOMETRE = | 1000 = | 3280·869 feet. / 1093·623 yds. / ·62138mle. |
| 10 kilometres | = 1 myriametre = | 10,000 = | 6·21377 miles. |

### TABLE 48.—FRENCH MEASURES OF SURFACE.

| | | Sq. Metres. | English Equivalents. |
|---|---|---|---|
| | 1 sq. millimetre | ·000001 | ·00155 sq. in. |
| 100 square millimetres | 1 sq. centimetre . | ·0001 | ·155 sq. in. |
| 100 square centimetres. | 1 sq. decimetre . | ·01 | 15·5003 sq. ins. |
| 100 square decimetres. 10,000 square centimetres. | 1 square metre or centiare . . | 1 | 10·7641 sq. ft. / 1·1960 sq. yds. |
| 100 square metres. | 1 sq. decametre, or are . . . . | 100 | 1076·41 sq. ft. / 119·601 sq. yds. |
| 100 square decametres. | 1 sq. hectometre or hectare, or metrical acre . | 10,000 | 11,960·11 sq.yds. / 2·4711 acres. |
| 100 square hectometres. | 1 sq. kilometre . | 1,000,000 | 1,196,014 sq.yds. / ·38611 sq. mile. |
| 100 square kilometres. | 1 sq. myriametre . | 100,000,000 = | 38·611 sq.miles |

Land is measured in terms of the centiare, the are, and the hectare.

**Wood (France).**

The large pieces of timber, cut from the trees, are of the following ordinary squared sizes.

| | Metre. | Inches. |
|---|---|---|
| Oak . . . . . . . . . . | ·10 to ·30 | 3·94 to 11·8 |
| Small stowage (*Petit arrimage*) . | ·30 to ·40 | 11·8 to 15·7 |

| | Metre. | Inches. |
|---|---|---|
| Large stowage (*Gros arrimage*) . . | ·40 to ·60 | 15·7 to 23·6 |
| Fir . . . . . . . . . | ·18 to ·27 | 7·1 to 10·6 |
| do. beams . . . . . . . | ·27 to ·36 | 10·6 to 14·2 |
| do. large wood . . . . . . | ·36 to ·60 | 14·2 to 23·6 |

## Table 49.—Oak Scantlings in Commercial Use (France).

| Description. | Width. | | Thickness. | | Length. | |
|---|---|---|---|---|---|---|
| | Millimetres. | Inches. | Millimetres. | Inches. | Metres. | Feet. |
| Echantillon (sample) | 25 | ·98 | 42 | 1·65 | 1·5 to 4 | 4·9 to 13·2 |
| Membrure (frame) | 167 | 6·57 | 83 | 3·27 | 2 to 4 | 6·6 to 13·2 |
| Doublette (principal) | 333 | 11·93 | 63 | 2·48 | 2·5 to 4 | 8·2 to 13·2 |
| Grand Battant (large doorframe) | 333 | 11·93 | 126 | 4·96 | 4 to 6 | 13·1 to 19·7 |
| Petit Battant (small doorframe) | 25 | ·98 | 83 | 3·27 | 3 to 6 | 9·8 to 19·7 |
| Entrevous (between joists) | 25 | ·98 | 28 | 1·10 | 1·5 to 4 | 4·9 to 13·2 |
| Chevron (joist) | 83 | 3·27 | 83 | 3·27 | 2 to 4 | 6·6 to 13·2 |
| Membrette . | 167 | 6·57 | 56 | 2·20 | 1·5 to 4 | 4·9 to 13·2 |
| Panneau (panel) | 216 to 243 | 8·51 to 9·57 | 20 to 22 | ·79 to ·87 | 2 to 4 | 6·6 to 13·2 |
| Volige (thin plank) | 216 to 243 | 8·51 to 9·57 | 13 to 15 | ·51 to ·59 | 2 to 4 | 6·6 to 13·2 |
| Feuillet (edge of panel) | 216 to 243 | 8·51 to 9·57 | 6 to 7 | ·24 to ·28 | 2 to 4 | 6·6 to 13·2 |
| **Fir Scantlings.** | | | | | | |
| Madrier (plank-principal piece) | 220 | 8·66 | 80 | 3·15 | ... | ... |
| Petit Madrier (smaller piece) | 220 | 8·66 | 54 | 2·13 | ... | ... |
| Planche (board) | 220 or 320 | 8·66 or 12·60 | 27 | 1·06 | ... | ... |

## Table 50.—French Measures of Volume.

### Cubic Measure.

| | | Cubic Metres. | English Equivalents. |
|---|---|---|---|
| | 1 cubic millimetre | ·000000001 | ·000061 cubic inch. |
| 1000 cubic millimetres | 1 cubic centimetre | ·000001 | ·061025 cubic inch. |
| 1000 cubic centimetres | 1 cubic decimetre | ·001 | 61·02524 cubic ins.<br>·0353156 cubic ft. |
| 1000 cubic decimeters | 1 cubic metre | 1 | 35·3156 cubic feet.<br>1·308 cubic yards. |
| 1000 cubic metres | 1 cubic decametre | 1,000 | 1308 cubic yards. |

### Firewood Measure (French).

| | | Cubic Metres. | |
|---|---|---|---|
| | 1 decistère | 0·1 | 3·532 cubic feet. |
| 10 decistères | 1 stère (cubic metre) | 1 | 35·3156 cubic feet. |
| 1 vois (Paris) | 2 stères | 2 | 70·6312 cubic feet. |
| 1 vois de charbon (charcoal) | 0·2 stère | 0·2 | 7·063 cubic feet. |
| 1 corde | 4 stères | 4 | 141·2624 „ |
| 1 decastère | 10 stères | 10 | 353·156 „ |

The stère measures 1·14 metres × 0·88 metre, by 1 metre, the billets being 1·14 metres in length.

### Liquid Measure.

| | | Litres. | |
|---|---|---|---|
| | 1 centilitre<br>10 cubic centimetres | ·01 | ·61025 cubic inch.<br>·0704 gill. |
| 10 centilitres | 1 décilitre | 0·1 | 6·1025 cubic inches.<br>·1761 pint. |
| 10 décilitres | 1 LITRE (1 cubic decimetre) | 1 | 61·02524 cubic ins.<br>·2201 gallon. |
| 10 litres | 1 décalitre | 10 | 2·2009 gallons. |
| 10 décalitres | 1 hectolitre | 100 | 22·009 gallons. |

### Dry Measure.

| | | | |
|---|---|---|---|
| 10 litres | 1 décalitre | 10 | 2·2009 gallons. |
| 10 décalitres | 1 hectolitre | 100 | 22·009 gallons.<br>2·7511 bushels. |
| 10 hectolitres | 1 kilolitre. (1 cubic metre) | 1000 | 220·09 gallons.<br>27·511 bushels. |

The use of measures equal to a *double-litre*, a *half-litre*, a *double-décilitre*, a *half-décilitre*, is sanctioned by law.

## TABLE 51.—FRENCH MEASURES OF WEIGHT.

| | | Grammes. | English Equivalents. |
|---|---|---|---|
| | 1 milligramme . | ·001 | ·0154 grain. |
| 10 milligrammes . | 1 centigramme . | ·01 | ·1543 grain. |
| 10 centigrammes . | 1 decigramme . | 0·1 | 1·5432 grains. |
| 10 decigrammes . | 1 GRAMME (unit of weight) . | 1 | 15·4323 grains. |
| 10 grammes . . | 1 décagramme . | 10 | 154·3235 grains.<br>·3527 ounce. |
| 10 décagrammes. | 1 hectogramme | 100 | 1543·2349 grains.<br>3·5274 ounces. |
| 10 hectogrammes. | 1 KILOGRAMME | 1000 | 2·2046 pounds. |
| 100 kilogrammes . | 1 metric quintal | | 220·4621 pounds. |
| 10 quintals, or 1000 kilogrammes | 1 millier, or tonne . . | | 2204·6212 pounds.<br>19·6841 cwts.<br>·9842 ton. |

## TABLE 52.—MILLIMETRES IN LINEAL INCHES.

| Millimetres. | Inches. | Millimetres. | Inches. | Millimetres. | Inches. | Millimetres. | Inches. |
|---|---|---|---|---|---|---|---|
| 1 | ·0394 | 26 | 1·0236 | 51 | 2·0079 | 76 | 2·9922 |
| 2 | ·0787 | 27 | 1·0630 | 52 | 2·0473 | 77 | 3·0315 |
| 3 | ·1181 | 28 | 1·1024 | 53 | 2·0866 | 78 | 3·0709 |
| 4 | ·1575 | 29 | 1·1417 | 54 | 2·1260 | 79 | 3·1103 |
| 5 | ·1968 | 30 | 1·1811 | 55 | 2·1654 | 80 | 3·1496 |
| 6 | ·2362 | 31 | 1·2205 | 56 | 2·2047 | 81 | 3·1890 |
| 7 | ·2756 | 32 | 1·2598 | 57 | 2·2441 | 82 | 3·2284 |
| 8 | ·3150 | 33 | 1·2992 | 58 | 2·2835 | 83 | 3·2677 |
| 9 | ·3543 | 34 | 1·3386 | 59 | 2·3228 | 84 | 3·3071 |
| 10 | ·3937 | 35 | 1·3780 | 60 | 2·3622 | 85 | 3·3465 |
| 11 | ·4331 | 36 | 1·4173 | 61 | 2·4016 | 86 | 3·3859 |
| 12 | ·4724 | 37 | 1·4567 | 62 | 2·4410 | 87 | 3·4252 |
| 13 | ·5118 | 38 | 1·4961 | 63 | 2·4803 | 88 | 3·4646 |
| 14 | ·5512 | 39 | 1·5354 | 64 | 2·5197 | 89 | 3·5040 |
| 15 | ·5906 | 40 | 1·5748 | 65 | 2·5591 | 90 | 3·5433 |
| 16 | ·6299 | 41 | 1·6142 | 66 | 2·5984 | 91 | 3·5827 |
| 17 | ·6693 | 42 | 1·6536 | 67 | 2·6378 | 92 | 3·6221 |
| 18 | ·7087 | 43 | 1·6929 | 68 | 2·6772 | 93 | 3·6614 |
| 19 | ·7480 | 44 | 1·7323 | 69 | 2·7166 | 94 | 3·7008 |
| 20 | ·7874 | 45 | 1·7717 | 70 | 2·7559 | 95 | 3·7402 |
| 21 | ·8268 | 46 | 1·8110 | 71 | 2·7953 | 96 | 3·7796 |
| 22 | ·8661 | 47 | 1·8504 | 72 | 2·8347 | 97 | 3·8189 |
| 23 | ·9055 | 48 | 1·8898 | 73 | 2·8740 | 98 | 3·8583 |
| 24 | ·9449 | 49 | 1·9291 | 74 | 2·9134 | 99 | 3·8977 |
| 25 | ·9843 | 50 | 1·9685 | 75 | 2·9528 | 100 | 3·9370 |

TABLE 52.—MILLIMETRES IN LINEAL INCHES (*continued*).

| Milli-metres. | Inches. | Milli-metres. | Inches. | Milli-metres. | Inches. | Milli-metres. | Inches. |
|---|---|---|---|---|---|---|---|
| 101 | 3·9764 | 143 | 5·6300 | 185 | 7·2835 | 227 | 8·9371 |
| 102 | 4·0158 | 144 | 5·6693 | 186 | 7·3229 | 228 | 8·9765 |
| 103 | 4·0552 | 145 | 5·7087 | 187 | 7·3623 | 229 | 9·0158 |
| 104 | 4·0945 | 146 | 5·7481 | 188 | 7·4016 | 230 | 9·0552 |
| 105 | 4·1339 | 147 | 5·7874 | 189 | 7·4410 | 231 | 9·0946 |
| 106 | 4·1733 | 148 | 5·8268 | 190 | 7·4804 | 232 | 9·1339 |
| 107 | 4·2126 | 149 | 5·8662 | 191 | 7·5198 | 233 | 9·1733 |
| 108 | 4·2520 | 150 | 5·9056 | 192 | 7·5591 | 234 | 9·2127 |
| 109 | 4·2914 | 151 | 5·9449 | 193 | 7·5985 | 235 | 9·2521 |
| 110 | 4·3307 | 152 | 5·9843 | 194 | 7·6379 | 236 | 9·2914 |
| 111 | 4·3701 | 153 | 6·0237 | 195 | 7·6772 | 237 | 9·3308 |
| 112 | 4·4095 | 154 | 6·0630 | 196 | 7·7166 | 238 | 9·3702 |
| 113 | 4·4489 | 155 | 6·1024 | 197 | 7·7560 | 239 | 9·4095 |
| 114 | 4·4882 | 156 | 6·1418 | 198 | 7·7954 | 240 | 9·4489 |
| 115 | 4·5276 | 157 | 6·1812 | 199 | 7·8347 | 241 | 9·4883 |
| 116 | 4·5670 | 158 | 6·2205 | 200 | 7·8741 | 242 | 9·5277 |
| 117 | 4·6063 | 159 | 6·2599 | 201 | 7·9135 | 243 | 9·5670 |
| 118 | 4·6457 | 160 | 6·2993 | 202 | 7·9528 | 244 | 9·6064 |
| 119 | 4·6851 | 161 | 6·3386 | 203 | 7·9922 | 245 | 9·6458 |
| 120 | 4·7245 | 162 | 6·3780 | 204 | 8·0316 | 246 | 9·6851 |
| 121 | 4·7638 | 163 | 6·4174 | 205 | 8·0709 | 247 | 9·7245 |
| 122 | 4·8032 | 164 | 6·4568 | 206 | 8·1103 | 248 | 9·7639 |
| 123 | 4·8426 | 165 | 6·4961 | 207 | 8·1497 | 249 | 9·8032 |
| 124 | 4·8819 | 166 | 6·5355 | 208 | 8·1891 | 250 | 9·8426 |
| 125 | 4·9213 | 167 | 6·5749 | 209 | 8·2284 | 251 | 9·8820 |
| 126 | 4·9607 | 168 | 6·6142 | 210 | 8·2678 | 252 | 9·9214 |
| 127 | 5·0000 | 169 | 6·6536 | 211 | 8·3072 | 253 | 9·9607 |
| 128 | 5·0394 | 170 | 6·6930 | 212 | 8·3465 | 254 | 10·0001 |
| 129 | 5·0788 | 171 | 6·7323 | 213 | 8·3859 | 255 | 10·0395 |
| 130 | 5·1182 | 172 | 6·7717 | 214 | 8·4253 | 256 | 10·0788 |
| 131 | 5·1575 | 173 | 6·8111 | 215 | 8·4646 | 257 | 10·1182 |
| 132 | 5·1969 | 174 | 6·8505 | 216 | 8·5040 | 258 | 10·1576 |
| 133 | 5·2363 | 175 | 6·8898 | 217 | 8·5434 | 259 | 10·1970 |
| 134 | 5·2756 | 176 | 6·9292 | 218 | 8·5828 | 260 | 10·2363 |
| 135 | 5·3150 | 177 | 6·9686 | 219 | 8·6221 | 261 | 10·2757 |
| 136 | 5·3544 | 178 | 7·0079 | 220 | 8·6615 | 262 | 10·3151 |
| 137 | 5·3938 | 179 | 7·0473 | 221 | 8·7009 | 263 | 10·3544 |
| 138 | 5·4331 | 180 | 7·0867 | 222 | 8·7402 | 264 | 10·3938 |
| 139 | 5·4725 | 181 | 7·1261 | 223 | 8·7796 | 265 | 10·4332 |
| 140 | 5·5119 | 182 | 7·1654 | 224 | 8·8190 | 266 | 10·4725 |
| 141 | 5·5512 | 183 | 7·2048 | 225 | 8·8584 | 267 | 10·5119 |
| 142 | 5·5906 | 184 | 7·2442 | 226 | 8·8977 | 268 | 10·5513 |

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TABLE 52.—MILLIMETRES IN LINEAL INCHES (*continued*).

| Milli-metres. | Inches. | Milli-metres. | Inches. | Milli-metres. | Inches. | Milli-metres. | Inches. |
|---|---|---|---|---|---|---|---|
| **269** | 10·5907 | **311** | 12·2442 | **353** | 13·8978 | **395** | 15·5513 |
| **270** | 10·6300 | **312** | 12·2836 | **354** | 13·9371 | **396** | 15·5907 |
| **271** | 10·6694 | **313** | 12·3229 | **355** | 13·9765 | **397** | 15·6300 |
| **272** | 10·7088 | **314** | 12·3623 | **356** | 14·0159 | **398** | 15·6694 |
| **273** | 10·7481 | **315** | 12·4017 | **357** | 14·0552 | **399** | 15·7088 |
| **274** | 10·7875 | **316** | 12·4410 | **358** | 14·0946 | **400** | 15·7482 |
| **275** | 10·8269 | **317** | 12·4804 | **359** | 14·1340 | **401** | 15·7875 |
| **276** | 10·8663 | **318** | 12·5198 | **360** | 14·1733 | **402** | 15·8269 |
| **277** | 10·9056 | **319** | 12·5592 | **361** | 14·2127 | **403** | 15·8663 |
| **278** | 10·9450 | **320** | 12·5985 | **362** | 14·2521 | **404** | 15·9056 |
| **279** | 10·9844 | **321** | 12·6379 | **363** | 14·2915 | **405** | 15·9450 |
| **280** | 11·0237 | **322** | 12·6773 | **364** | 14·3308 | **406** | 15·9844 |
| **281** | 11·0361 | **323** | 12·7166 | **365** | 14·3702 | **407** | 16·0238 |
| **282** | 11·1025 | **324** | 12·7560 | **366** | 14·4096 | **408** | 16·0631 |
| **283** | 11·1419 | **325** | 12·7954 | **367** | 14·4489 | **409** | 16·1025 |
| **284** | 11·1812 | **326** | 12·8348 | **368** | 14·4883 | **410** | 16·1419 |
| **285** | 11·2206 | **327** | 12·8741 | **369** | 14·5277 | **411** | 16·1812 |
| **286** | 11·2600 | **328** | 12·9135 | **370** | 14·5670 | **412** | 16·2206 |
| **287** | 11·2993 | **329** | 12·9529 | **371** | 14·6064 | **413** | 16·2600 |
| **288** | 11·3387 | **330** | 12·9922 | **372** | 14·6458 | **414** | 16·2993 |
| **289** | 11·3781 | **331** | 13·0316 | **373** | 14·6852 | **415** | 16·3387 |
| **290** | 11·4174 | **332** | 13·0710 | **374** | 14·7245 | **416** | 16·3781 |
| **291** | 11·4568 | **333** | 13·1103 | **375** | 14·7639 | **417** | 16·4175 |
| **292** | 11·4962 | **334** | 13·1497 | **376** | 14·8033 | **418** | 16·4568 |
| **293** | 11·5356 | **335** | 13·1891 | **377** | 14·8426 | **419** | 16·4962 |
| **294** | 11·5749 | **336** | 13·2285 | **378** | 14·8820 | **420** | 16·5356 |
| **295** | 11·6143 | **337** | 13·2678 | **379** | 14·9214 | **421** | 16·5749 |
| **296** | 11·6537 | **338** | 13·3072 | **380** | 14·9608 | **422** | 16·6143 |
| **297** | 11·6930 | **339** | 13·3466 | **381** | 15·0001 | **423** | 16·6537 |
| **298** | 11·7324 | **340** | 13·3859 | **382** | 15·0395 | **424** | 16·6930 |
| **299** | 11·7718 | **341** | 13·4253 | **383** | 15·0789 | **425** | 16·7324 |
| **300** | 11·8111 | **342** | 13·4647 | **384** | 15·1182 | **426** | 16·7718 |
| **301** | 11·8505 | **343** | 13·5040 | **385** | 15·1576 | **427** | 16·8112 |
| **302** | 11·8899 | **344** | 13·5434 | **386** | 15·1970 | **428** | 16·8505 |
| **303** | 11·9292 | **345** | 13·5828 | **387** | 15·2363 | **429** | 16·8899 |
| **304** | 11·9686 | **346** | 13·6222 | **388** | 15·2757 | **430** | 16·9293 |
| **305** | 12·0080 | **347** | 13·6615 | **389** | 15·3151 | **431** | 16·9686 |
| **306** | 12·0473 | **348** | 13·7009 | **390** | 15·3545 | **432** | 17·0080 |
| **307** | 12·0867 | **349** | 13·7403 | **391** | 15·3938 | **433** | 17·0474 |
| **308** | 12·1261 | **350** | 13·7790 | **392** | 15·4332 | **434** | 17·0868 |
| **309** | 12·1655 | **351** | 13·8190 | **393** | 15·4726 | **435** | 17·1261 |
| **310** | 12·2048 | **352** | 13·8584 | **394** | 15·5119 | **436** | 17·1655 |

TABLE 52.—MILLIMETRES IN LINEAL INCHES (*continued*).

| Milli-metres. | Inches. | Milli-metres. | Inches. | Milli-metres. | Inches. | Milli-metres. | Inches. |
|---|---|---|---|---|---|---|---|
| **437** | 17·2049 | **456** | 17·9529 | **475** | 18·7009 | **494** | 19·4490 |
| **438** | 17·2442 | **457** | 17·9923 | **476** | 18·7403 | **495** | 19·4883 |
| **439** | 17·2836 | **458** | 18·0316 | **477** | 18·7797 | **496** | 19·5277 |
| **440** | 17·3230 | **459** | 18·0710 | **478** | 18·8191 | **497** | 19·5671 |
| **441** | 17·3623 | **460** | 18·1104 | **479** | 18·8584 | **498** | 19·6065 |
| **442** | 17·4017 | **461** | 18·1498 | **480** | 18·8978 | **499** | 19·6458 |
| **443** | 17·4411 | **462** | 18·1891 | **481** | 18·9372 | **500** | 19·6852 |
| **444** | 17·4805 | **463** | 18·2285 | **482** | 18·9765 | **550** | 21·6537 |
| **445** | 17·5198 | **464** | 18·2679 | **483** | 19·0159 | **600** | 23·6223 |
| **446** | 17·5592 | **465** | 18·3072 | **484** | 19·0553 | **650** | 25·5908 |
| **447** | 17·5986 | **466** | 18·3466 | **485** | 19·0946 | **700** | 27·5593 |
| **448** | 17·6379 | **467** | 18·3860 | **486** | 19·1340 | **750** | 29·5278 |
| **449** | 17·6773 | **468** | 18·4253 | **487** | 19·1734 | **800** | 31·4963 |
| **450** | 17·7167 | **469** | 18·4647 | **488** | 19·2128 | **850** | 33·4649 |
| **451** | 17·7561 | **470** | 18·5041 | **489** | 19·2521 | **900** | 35·4334 |
| **452** | 17·7954 | **471** | 18·5435 | **490** | 19·2915 | **950** | 37·4019 |
| **453** | 17·8350 | **472** | 18·5828 | **491** | 19·3309 | **1000** | 39·3704 |
| **454** | 17·8742 | **473** | 18·6222 | **492** | 19·3702 | | = 1 |
| **455** | 17·9135 | **474** | 18·6616 | **493** | 19·4096 | | metre. |

By means of the above Table, and the following Table 53, the equivalent values of inches in centimetres and decimetres, and even in metres, may be found by simply altering the position of the decimal point. Take for example the tabular value of 2 millimetres, Table 52, and shift the decimal point successively, by one digit, towards the right-hand side; the values of two centimetres, two decimetres, and two metres are thereby expressed in inches, as follows :—

| | | |
|---|---|---|
| 2 millimetres . . . . . . | ·0787 | inches. |
| 2 centimetres . . . . . . . | 0·787 | „ |
| 2 decimetres . . . . . . . | 7·87 | „ |
| 2 metres . . . . . . . . | 78·7 | „ |

At the same time, it appears that, by selecting the tabular value of 20 millimetres, the value of its multiples are given more accurately, thus,—

| | | |
|---|---|---|
| 20 millimetres, or 2 centimetres . | 0·7874 | inches. |
| 2 decimetres. . . . . . . . | 7·874 | „ |
| 2 metres . . . . . . . . . | 78·74 | „ |

Again :—

| | | | |
|---|---|---|---|
| 200 millimetres, or 2 decimetres | = | 7·8741 inches | |
| 2 metres . . . . . | = | 78·741 | „ |

Similarly, for example :—

| | | | | |
|---|---|---|---|---|
| ·32 inch | = | 8·128 millimetres. | | |
| 3·2 „ | = | 81·28 | „ | |
| 32·0 „ | = | 812·8 | „ | or |
| | | ·8128 metre. | | |

Like functional expansions of the following tables of relative French and English measures and weight, are available for practice : greatly extending the utility of the tables.

TABLE 53.—DECIMAL FRACTIONS OF A LINEAL INCH IN MILLIMETRES.

| Inch. | Millimetres. | Inch. | Millimetres. | Inch. | Millimetres. | Inches. | Millimetres. |
|---|---|---|---|---|---|---|---|
| ·01 | ·254 | ·29 | 7·366 | ·57 | 14·478 | ·85 | 21·590 |
| ·02 | ·508 | ·30 | 7·620 | ·58 | 14·732 | ·86 | 21·844 |
| ·03 | ·762 | ·31 | 7·874 | ·59 | 14·986 | ·87 | 22·098 |
| ·04 | 1·016 | ·32 | 8·128 | ·60 | 15·240 | ·88 | 22·352 |
| ·05 | 1·270 | ·33 | 8·382 | ·61 | 15·494 | ·89 | 22·606 |
| ·06 | 1·524 | ·34 | 8·636 | ·62 | 15·748 | ·90 | 22·860 |
| ·07 | 1·778 | ·35 | 8·890 | ·63 | 16·002 | ·91 | 23·114 |
| ·08 | 2·032 | ·36 | 9·144 | ·64 | 16·256 | ·92 | 23·368 |
| ·09 | 2·286 | ·37 | 9·398 | ·65 | 16·510 | ·93 | 23·622 |
| ·10 | 2·540 | ·38 | 9·652 | ·66 | 16·764 | ·94 | 23·876 |
| ·11 | 2·794 | ·39 | 9·906 | ·67 | 17·018 | ·95 | 24·130 |
| ·12 | 3·048 | ·40 | 10·160 | ·68 | 17·272 | ·96 | 24·384 |
| ·13 | 3·302 | ·41 | 10·414 | ·69 | 17·526 | ·97 | 24·638 |
| ·14 | 3·556 | ·42 | 10·668 | ·70 | 17·780 | ·98 | 24·892 |
| ·15 | 3·810 | ·43 | 10·922 | ·71 | 18·034 | ·99 | 25·146 |
| ·16 | 4·064 | ·44 | 11·176 | ·72 | 18·288 | 1·00 | 25·400 |
| ·17 | 4·318 | ·45 | 11·430 | ·73 | 18·542 | 2·00 | 50·799 |
| ·18 | 4·572 | ·46 | 11·684 | ·74 | 18·796 | 3·00 | 76·199 |
| ·19 | 4·826 | ·47 | 11·938 | ·75 | 19·050 | 4·00 | 101·598 |
| ·20 | 5·080 | ·48 | 12·192 | ·76 | 19·304 | 5·00 | 126·998 |
| ·21 | 5·334 | ·49 | 12·446 | ·77 | 19·558 | 6·00 | 152·397 |
| ·22 | 5·588 | ·50 | 12·700 | ·78 | 19·812 | 7·00 | 177·797 |
| ·23 | 5·842 | ·51 | 12·954 | ·79 | 20·066 | 8·00 | 203·196 |
| ·24 | 6·096 | ·52 | 13·208 | ·80 | 20·320 | 9·00 | 228·596 |
| ·25 | 6·350 | ·53 | 13·462 | ·81 | 20·574 | 10·00 | 253·995 |
| ·26 | 6·604 | ·54 | 13·716 | ·82 | 20·828 | 11·00 | 279·395 |
| ·27 | 6·858 | ·55 | 13·970 | ·83 | 21·082 | 12·00 =1 foot | 304·794 |
| ·28 | 7·112 | ·56 | 14·224 | ·84 | 21·336 | | |

TABLE 54.—VULGAR FRACTIONS OF A LINEAL INCH IN MILLIMETRES.

| Eighths of an Inch. | Millimetres. | Eighths of an Inch. | Millimetres. | Eighths of an Inch. | Millimetres. |
|---|---|---|---|---|---|
| 1 | 3·175 | 4 | 12·700 | 7 | 22·225 |
| 2 | 6·350 | 5 | 15·875 | 8 | 25·400 |
| 3 | 9·525 | 6 | 19·050 | | |

| Twelfths of an Inch. | Millimetres. | Twelfths of an Inch. | Millimetres. | Twelfths of an Inch. | Millimetres. |
|---|---|---|---|---|---|
| 1 | 2·117 | 5 | 10·583 | 9 | 19·050 |
| 2 | 4·233 | 6 | 12·700 | 10 | 21·166 |
| 3 | 6·350 | 7 | 14·816 | 11 | 23·283 |
| 4 | 8·466 | 8 | 16·933 | 12 | 25·400 |

| Sixteenths of an Inch. | Millimetres. | Sixteenths of an Inch. | Millimetres. | Sixteenths of an Inch. | Millimetres. |
|---|---|---|---|---|---|
| 1 | 1·587 | 7 | 11·112 | 13 | 20·637 |
| 3 | 4·762 | 9 | 14·287 | 15 | 23·812 |
| 5 | 7·937 | 11 | 17·462 | | |

| Thirty-seconds of an Inch. | Millimetres. | Thirty-seconds of an Inch. | Millimetres. | Thirty-seconds of an Inch. | Millimetres. |
|---|---|---|---|---|---|
| 1 | 0·794 | 13 | 10·319 | 25 | 19·843 |
| 3 | 2·381 | 15 | 11·906 | 27 | 21·431 |
| 5 | 3·969 | 17 | 13·493 | 29 | 23·018 |
| 7 | 5·556 | 19 | 15·081 | 31 | 24·606 |
| 9 | 7·144 | 21 | 16·668 | | |
| 11 | 8·731 | 23 | 18·256 | | |

| Sixty-fourths of an Inch. | Millimetres. | Sixty-fourths of an Inch. | Millimetres. | Sixty-fourths of an Inch. | Millimetres. |
|---|---|---|---|---|---|
| 1 | 0·397 | 23 | 9·128 | 45 | 17·859 |
| 3 | 1·191 | 25 | 9·922 | 47 | 18·653 |
| 5 | 1·984 | 27 | 10·715 | 49 | 19·447 |
| 7 | 2·778 | 29 | 11·509 | 51 | 20·240 |
| 9 | 3·572 | 31 | 12·303 | 53 | 21·034 |
| 11 | 4·366 | 33 | 13·097 | 55 | 21·828 |
| 13 | 5·159 | 35 | 13·890 | 57 | 22·621 |
| 15 | 5·953 | 37 | 14·684 | 59 | 23·415 |
| 17 | 6·747 | 39 | 15·478 | 61 | 24·209 |
| 19 | 7·540 | 41 | 16·272 | 63 | 25·003 |
| 21 | 8·334 | 43 | 17·065 | | |

## TABLE 55.—METRES IN LINEAL FEET AND IN YARDS.

| Metres. | Feet. | Yards. | Metres. | Feet. | Yards. |
|---|---|---|---|---|---|
| **1** | 3·2809 | 1·0936 | **44** | 144·3596 | 48·1193 |
| **2** | 6·5618 | 2·1872 | **45** | 147·6405 | 49·2129 |
| **3** | 9·8427 | 3·2809 | **46** | 150·9214 | 50·3065 |
| **4** | 13·1236 | 4·3745 | **47** | 154·2023 | 51·4001 |
| **5** | 16·4045 | 5·4681 | **48** | 157·4832 | 52·4938 |
| **6** | 19·6854 | 6·5617 | **49** | 160·7641 | 53·5874 |
| **7** | 22·9663 | 7·6553 | **50** | 164·0450 | 54·6810 |
| **8** | 26·2472 | 8·7490 | **51** | 167·3259 | 55·7746 |
| **9** | 29·5281 | 9·8426 | **52** | 170·6068 | 56·8682 |
| **10** | 32·8090 | 10·9362 | **53** | 173·8877 | 57·9619 |
| **11** | 36·0899 | 12·0298 | **54** | 177·1686 | 59·0555 |
| **12** | 39·3708 | 13·1234 | **55** | 180·4495 | 60·1491 |
| **13** | 42·6517 | 14·2171 | **56** | 183·7304 | 61·2427 |
| **14** | 45·9326 | 15·3107 | **57** | 187·0113 | 62·3363 |
| **15** | 49·2135 | 16·4043 | **58** | 190·2922 | 63·4300 |
| **16** | 52·4944 | 17·4979 | **59** | 193·5731 | 64·5236 |
| **17** | 55·7753 | 18·5915 | **60** | 196·8540 | 65·6172 |
| **18** | 59·0562 | 19·6852 | **61** | 200·1349 | 66·7108 |
| **19** | 62·3371 | 20·7788 | **62** | 203·4158 | 67·8044 |
| **20** | 65·6180 | 21·8724 | **63** | 206·6967 | 68·8981 |
| **21** | 68·8989 | 23·9660 | **64** | 209·9776 | 69·9917 |
| **22** | 72·1798 | 24·0596 | **65** | 213·2585 | 71·0853 |
| **23** | 75·4607 | 25·1533 | **66** | 216·5394 | 72·1789 |
| **24** | 78·7416 | 26·2469 | **67** | 219·8203 | 73·2725 |
| **25** | 82·0225 | 27·3405 | **68** | 223·1012 | 74·3662 |
| **26** | 85·3034 | 28·4341 | **69** | 226·3821 | 75·4598 |
| **27** | 88·5843 | 29·5277 | **70** | 229·6630 | 76·5534 |
| **28** | 91·8652 | 30·6214 | **71** | 232·9439 | 77·6470 |
| **29** | 95·1461 | 31·7150 | **72** | 236·2248 | 78·7406 |
| **30** | 98·4270 | 32·8086 | **73** | 239·5057 | 79·8343 |
| **31** | 101·7079 | 33·9022 | **74** | 242·7866 | 80·9279 |
| **32** | 104·9888 | 34·9958 | **75** | 246·0675 | 82·0215 |
| **33** | 108·2697 | 36·0895 | **76** | 249·3484 | 83·1151 |
| **34** | 111·5506 | 37·1831 | **77** | 252·6293 | 84·2087 |
| **35** | 114·8315 | 38·2767 | **78** | 255·9102 | 85·3024 |
| **36** | 118·1124 | 39·3703 | **79** | 259·1911 | 86·3960 |
| **37** | 121·3933 | 40·4639 | **80** | 262·4720 | 87·4896 |
| **38** | 124·6742 | 41·5576 | **81** | 265·7529 | 88·5832 |
| **39** | 127·9551 | 42·6512 | **82** | 269·0338 | 89·6768 |
| **40** | 131·2360 | 43·7448 | **83** | 272·3147 | 90·7705 |
| **41** | 134·5169 | 44·8384 | **84** | 275·5956 | 91·8641 |
| **42** | 137·7978 | 45·9320 | **85** | 278·8765 | 92·9577 |
| **43** | 141·0787 | 47·0257 | **86** | 282·1574 | 94·0513 |

TABLE 55.—METRES IN LINEAL FEET AND IN YARDS (*continued*).

| Metres. | Feet. | Yards. | Metres. | Feet. | Yards. |
|---|---|---|---|---|---|
| **87** | 285·4383 | 95·1449 | **94** | 308·4046 | 102·8003 |
| **88** | 288·7192 | 96·2386 | **95** | 311·6855 | 103·8939 |
| **89** | 292·0001 | 97·3322 | **96** | 314·9664 | 104·9875 |
| **90** | 295·2810 | 98·4258 | **97** | 318·2473 | 106·0811 |
| **91** | 298·5619 | 99·5194 | **98** | 321·5282 | 107·1748 |
| **92** | 301·8428 | 100·6130 | **99** | 324·8091 | 108·2684 |
| **93** | 305·1237 | 101·7067 | **100** | 328·0900 | 109·3620 |

TABLE 56.—LINEAL FEET IN METRES.

| Feet. | Metres. | Feet. | Metres. | Feet. | Metres. | Feet. | Metres. |
|---|---|---|---|---|---|---|---|
| **1** | ·3048 | **26** | 7·9248 | **51** | 15·5448 | **76** | 23·1648 |
| **2** | ·6096 | **27** | 8·2296 | **52** | 15·8496 | **77** | 23·4696 |
| **3** | ·9144 | **28** | 8·5344 | **53** | 16·1544 | **78** | 23·7744 |
| **4** | 1·2192 | **29** | 8·8392 | **54** | 16·4592 | **79** | 24·0792 |
| **5** | 1·5240 | **30** | 9·1440 | **55** | 16·7640 | **80** | 24·3840 |
| **6** | 1·8288 | **31** | 9·4488 | **56** | 17·0688 | **81** | 24·6888 |
| **7** | 2·1336 | **32** | 9·7536 | **57** | 17·3736 | **82** | 24·9936 |
| **8** | 2·4384 | **33** | 10·0584 | **58** | 17·6784 | **83** | 25·2984 |
| **9** | 2·7432 | **34** | 10·3632 | **59** | 17·9832 | **84** | 25·6032 |
| **10** | 3·0480 | **35** | 10·6680 | **60** | 18·2880 | **85** | 25·9080 |
| **11** | 3·3528 | **36** | 10·9728 | **61** | 18·5928 | **86** | 26·2128 |
| **12** | 3·6576 | **37** | 11·2776 | **62** | 18·8976 | **87** | 26·5176 |
| **13** | 3·9624 | **38** | 11·5824 | **63** | 19·2024 | **88** | 26·8224 |
| **14** | 4·2672 | **39** | 11·8872 | **64** | 19·5072 | **89** | 27·1272 |
| **15** | 4·5720 | **40** | 12·1920 | **65** | 19·8120 | **90** | 27·4320 |
| **16** | 4·8768 | **41** | 12·4968 | **66** | 20·1168 | **91** | 27·7368 |
| **17** | 5·1816 | **42** | 12·8016 | **67** | 20·4216 | **92** | 28·0416 |
| **18** | 5·4864 | **43** | 13·1064 | **68** | 20·7264 | **93** | 28·3464 |
| **19** | 5·7912 | **44** | 13·4112 | **69** | 21·0312 | **94** | 28·6512 |
| **20** | 6·0960 | **45** | 13·7160 | **70** | 21·3360 | **95** | 28·9560 |
| **21** | 6·4008 | **46** | 14·0208 | **71** | 21·6408 | **96** | 29·2608 |
| **22** | 6·7056 | **47** | 14·3256 | **72** | 21·9456 | **97** | 29·5656 |
| **23** | 7·0104 | **48** | 14·6304 | **73** | 22·2504 | **98** | 29·8704 |
| **24** | 7·3152 | **49** | 14·9352 | **74** | 22·5552 | **99** | 30·1752 |
| **25** | 7·6200 | **50** | 15·2400 | **75** | 22·8600 | **100** | 30·4800 |

## Table 57.—Lineal Yards in Metres.

| Yards. | Metres. | Yards. | Metres. | Yards. | Metres. | Yards. | Metres. |
|---|---|---|---|---|---|---|---|
| 1 | ·9144 | 26 | 23·7741 | 51 | 46·6339 | 76 | 69·4936 |
| 2 | 1·8288 | 27 | 24·6885 | 52 | 47·5483 | 77 | 70·4080 |
| 3 | 2·7432 | 28 | 25·6029 | 53 | 48·4627 | 78 | 71·3224 |
| 4 | 3·6576 | 29 | 26·5173 | 54 | 49·3771 | 79 | 72·2368 |
| 5 | 4·5719 | 30 | 27·4317 | 55 | 50·2914 | 80 | 73·1512 |
| 6 | 5·4863 | 31 | 28·3461 | 56 | 51·2058 | 81 | 74·0656 |
| 7 | 6·4007 | 32 | 29·2605 | 57 | 52·1202 | 82 | 74·9800 |
| 8 | 7·3151 | 33 | 30·1749 | 58 | 53·0346 | 83 | 75·8944 |
| 9 | 8·2295 | 34 | 31·0893 | 59 | 53·9490 | 84 | 76·8088 |
| 10 | 9·1439 | 35 | 32·0036 | 60 | 54·8634 | 85 | 77·7231 |
| 11 | 10·0583 | 36 | 32·9180 | 61 | 55·7778 | 86 | 78·6375 |
| 12 | 10·9727 | 37 | 33·8324 | 62 | 56·6922 | 87 | 79·5519 |
| 13 | 11·8871 | 38 | 34·7468 | 63 | 57·6066 | 88 | 80·4663 |
| 14 | 12·8015 | 39 | 35·6612 | 64 | 58·5210 | 89 | 81·3807 |
| 15 | 13·7158 | 40 | 36·5756 | 65 | 59·4353 | 90 | 82·2951 |
| 16 | 14·6302 | 41 | 37·4900 | 66 | 60·3497 | 91 | 83·2095 |
| 17 | 15·5446 | 42 | 38·4044 | 67 | 61·2641 | 92 | 84·1239 |
| 18 | 16·4590 | 43 | 39·3188 | 68 | 62·1785 | 93 | 85·0383 |
| 19 | 17·3734 | 44 | 40·2332 | 69 | 63·0929 | 94 | 85·9527 |
| 20 | 18·2878 | 45 | 41·1475 | 70 | 64·0073 | 95 | 86·8670 |
| 21 | 19·2022 | 46 | 42·0619 | 71 | 64·9217 | 96 | 87·7814 |
| 22 | 20·1166 | 47 | 42·9763 | 72 | 65·8361 | 97 | 88·6958 |
| 23 | 21·0310 | 48 | 43·8907 | 73 | 66·7505 | 98 | 89·6102 |
| 24 | 21·9454 | 49 | 44·8051 | 74 | 67·6649 | 99 | 90·5246 |
| 25 | 22·8600 | 50 | 45·7195 | 75 | 68·5792 | 100 | 91·4390 |

## Table 58.—Kilogrammes in Pounds.

| Kilos. | Pounds. | Kilos. | Pounds. | Kilos. | Pounds. | Kilos. | Pounds. |
|---|---|---|---|---|---|---|---|
| 1 | 2·2046 | 13 | 28·6601 | 25 | 55·1155 | 37 | 81·5710 |
| 2 | 4·4092 | 14 | 30·8647 | 26 | 57·3201 | 38 | 83·7756 |
| 3 | 6·6139 | 15 | 33·0693 | 27 | 59·5248 | 39 | 85·9802 |
| 4 | 8·8185 | 16 | 35·2739 | 28 | 61·7294 | 40 | 88·1848 |
| 5 | 11·0231 | 17 | 37·4786 | 29 | 63·9340 | 41 | 90·3895 |
| 6 | 13·2277 | 18 | 39·6832 | 30 | 66·1386 | 42 | 92·5941 |
| 7 | 15·4323 | 19 | 41·8878 | 31 | 68·3433 | 43 | 94·7987 |
| 8 | 17·6370 | 20 | 44·0924 | 32 | 70·5479 | 44 | 97·0033 |
| 9 | 19·8416 | 21 | 46·2970 | 33 | 72·7525 | 45 | 99·2079 |
| 10 | 22·0462 | 22 | 48·5017 | 34 | 74·9571 | 46 | 101·4126 |
| 11 | 24·2508 | 23 | 50·7063 | 35 | 77·1617 | 47 | 103·6172 |
| 12 | 26·4555 | 24 | 52·9109 | 36 | 79·3664 | 48 | 105·8218 |

TABLE 58.—KILOGRAMMES IN POUNDS (*continued*).

| Kilos. | Pounds. | Kilos. | Pounds. | Kilos. | Pounds. | Kilos. | Pounds. |
|---|---|---|---|---|---|---|---|
| 49 | 108·0264 | 62 | 136·4865 | 75 | 165·3466 | 88 | 194·0066 |
| 50 | 110·2310 | 63 | 138·8911 | 76 | 167·5512 | 89 | 196·2113 |
| 51 | 112·4357 | 64 | 141·0957 | 77 | 169·7558 | 90 | 198·4159 |
| 52 | 114·6403 | 65 | 143·3004 | 78 | 171·9604 | 91 | 200·6205 |
| 53 | 116·8449 | 66 | 145·5050 | 79 | 174·1651 | 92 | 202·8251 |
| 54 | 119·0495 | 67 | 147·7096 | 80 | 176·3697 | 93 | 205·0298 |
| 55 | 121·2542 | 68 | 149·9142 | 81 | 178·5743 | 94 | 207·2344 |
| 56 | 123·4588 | 69 | 152·1188 | 82 | 180·7789 | 95 | 209·4390 |
| 57 | 125·6634 | 70 | 154·3235 | 83 | 182·9835 | 96 | 211·6436 |
| 58 | 127·8680 | 71 | 156·5281 | 84 | 185·1182 | 97 | 213·8482 |
| 59 | 130·0726 | 72 | 158·7327 | 85 | 187·3928 | 98 | 216·0529 |
| 60 | 132·2773 | 73 | 160·9373 | 86 | 189·5974 | 99 | 218·2575 |
| 61 | 134·4819 | 74 | 163·1420 | 87 | 191·8020 | 100 | 220·4621 |

TABLE 59.—POUNDS IN KILOGRAMMES.

| Pounds. | Kilogrs. | Pounds. | Kilogrs. | Pounds. | Kilogrs. | Pounds. | Kilogrs. |
|---|---|---|---|---|---|---|---|
| 1 | ·4536 | 26 | 11·7934 | 51 | 23·1332 | 76 | 34·4731 |
| 2 | ·9072 | 27 | 12·2470 | 52 | 23·5868 | 77 | 34·9267 |
| 3 | 1·3608 | 28 | 12·7006 | 53 | 24·0404 | 78 | 35·3803 |
| 4 | 1·8144 | 29 | 13·1542 | 54 | 24·4940 | 79 | 35·8338 |
| 5 | 2·2680 | 30 | 13·6078 | 55 | 24·9476 | 80 | 36·2874 |
| 6 | 2·7216 | 31 | 14·0614 | 56 | 25·4012 | 81 | 36·7410 |
| 7 | 3·1752 | 32 | 14·5150 | 57 | 25·8548 | 82 | 37·1946 |
| 8 | 3·6287 | 33 | 14·9686 | 58 | 26·3084 | 83 | 37·6482 |
| 9 | 4·0823 | 34 | 15·4222 | 59 | 26·7620 | 84 | 38·1018 |
| 10 | 4·5359 | 35 | 15·8758 | 60 | 27·2516 | 85 | 38·5554 |
| 11 | 4·9895 | 36 | 16·3293 | 61 | 27·6692 | 86 | 39·0090 |
| 12 | 5·4431 | 37 | 16·7829 | 62 | 28·1227 | 87 | 39·4626 |
| 13 | 5·8967 | 38 | 17·2365 | 63 | 28·5764 | 88 | 39·9162 |
| 14 | 6·3503 | 39 | 17·6901 | 64 | 29·0300 | 89 | 40·3700 |
| 15 | 6·8039 | 40 | 18·1437 | 65 | 29·4835 | 90 | 40·8234 |
| 16 | 7·2575 | 41 | 18·5973 | 66 | 29·9371 | 91 | 41·2770 |
| 17 | 7·7111 | 42 | 19·0509 | 67 | 30·3907 | 92 | 41·7306 |
| 18 | 8·1647 | 43 | 19·5045 | 68 | 30·8443 | 93 | 42·1841 |
| 19 | 8·6183 | 44 | 19·9581 | 69 | 31·2979 | 94 | 42·6377 |
| 20 | 9·0719 | 45 | 20·4117 | 70 | 31·7515 | 95 | 43·0913 |
| 21 | 9·5255 | 46 | 20·8653 | 71 | 32·2051 | 96 | 43·5449 |
| 22 | 9·9790 | 47 | 21·3189 | 72 | 32·6587 | 97 | 43·9985 |
| 23 | 10·4326 | 48 | 21·7725 | 73 | 33·1123 | 98 | 44·4521 |
| 24 | 10·8862 | 49 | 22·2261 | 74 | 33·5659 | 99 | 44·9057 |
| 25 | 11·3398 | 50 | 22·6796 | 75 | 34·0195 | 100 | 45·3593 |

TABLE 60.—SQUARE METRES IN SQUARE FEET AND SQUARE YARDS.

| Square Metres. | Square Feet. | Square Yards. | Square Metres. | Square Feet. | Square Yards. |
|---|---|---|---|---|---|
| 1 | 10·7641 | 1·1960 | 42 | 452·0930 | 50·2320 |
| 2 | 21·5282 | 2·3920 | 43 | 462·8572 | 51·4280 |
| 3 | 32·2924 | 3·5880 | 44 | 473·6213 | 52·6240 |
| 4 | 43·0565 | 4·7840 | 45 | 484·3854 | 53·8200 |
| 5 | 53·8206 | 5·9800 | 46 | 495·1495 | 55·0160 |
| 6 | 64·5847 | 7·1760 | 47 | 505·9136 | 56·2120 |
| 7 | 75·3458 | 8·3720 | 48 | 516·6778 | 57·4080 |
| 8 | 86·1130 | 9·5680 | 49 | 527·4419 | 58·6040 |
| 9 | 96·8771 | 10·7640 | 50 | 538·2060 | 59·8000 |
| 10 | 107·6412 | 11·9600 | 51 | 548·9701 | 60·9960 |
| 11 | 118·4053 | 13·1560 | 52 | 559·7342 | 62·1920 |
| 12 | 129·1694 | 14·3520 | 53 | 570·4984 | 63·3880 |
| 13 | 139·9336 | 15·5480 | 54 | 581·2625 | 64·5840 |
| 14 | 150·6977 | 16·7440 | 55 | 592·0266 | 65·7800 |
| 15 | 161·4618 | 17·9400 | 56 | 602·7907 | 66·9760 |
| 16 | 172·2259 | 19·1360 | 57 | 613·5548 | 68·1720 |
| 17 | 182·9900 | 20·3320 | 58 | 624·3190 | 69·3680 |
| 18 | 193·7542 | 21·5280 | 59 | 635·0831 | 70·5640 |
| 19 | 204·5183 | 22·7240 | 60 | 645·8472 | 71·7600 |
| 20 | 215·2824 | 23·9200 | 61 | 656·6113 | 72·9560 |
| 21 | 226·0465 | 25·1160 | 62 | 667·3754 | 74·1520 |
| 22 | 236·8106 | 26·3120 | 63 | 678·1396 | 75·3480 |
| 23 | 247·5748 | 27·5080 | 64 | 688·9037 | 76·5440 |
| 24 | 258·3389 | 28·7040 | 65 | 699·6678 | 77·7400 |
| 25 | 269·1030 | 29·9000 | 66 | 710·4319 | 78·9360 |
| 26 | 279·8671 | 31·0960 | 67 | 721·1960 | 80·1320 |
| 27 | 290·6312 | 32·2920 | 68 | 731·9602 | 81·3280 |
| 28 | 301·3954 | 33·4880 | 69 | 742·7243 | 82·5240 |
| 29 | 312·1595 | 34·6840 | 70 | 753·4884 | 83·7200 |
| 30 | 322·9236 | 35·8800 | 71 | 764·2525 | 84·9160 |
| 31 | 333·6877 | 37·0760 | 72 | 775·0166 | 86·1120 |
| 32 | 344·4518 | 38·2720 | 73 | 785·7808 | 87·3080 |
| 33 | 355·2160 | 39·4680 | 74 | 796·5449 | 88·5040 |
| 34 | 365·9801 | 40·6640 | 75 | 807·3090 | 89·7000 |
| 35 | 376·7442 | 41·8600 | 76 | 818·0731 | 90·8960 |
| 36 | 387·5083 | 43·0560 | 77 | 828·8372 | 92·0920 |
| 37 | 398·2724 | 44·2520 | 78 | 839·6014 | 93·2880 |
| 38 | 409·6366 | 45·4480 | 79 | 850·3655 | 94·4840 |
| 39 | 419·8007 | 46·6440 | 80 | 861·1296 | 95·6800 |
| 40 | 430·5648 | 47·8400 | 81 | 871·8937 | 96·8760 |
| 41 | 441·3289 | 49·0360 | 82 | 882·6578 | 98·0720 |

TABLE 60.—SQUARE METRES IN SQUARE FEET AND SQUARE YARDS (*continued*).

| Square Metres. | Square Feet. | Square Yards. | Square Metres. | Square Feet. | Square Yards. |
|---|---|---|---|---|---|
| **83** | 893·4220 | 99·2680 | **92** | 990·2990 | 110·0320 |
| **84** | 904·1861 | 100·4640 | **93** | 1001·0632 | 111·2280 |
| **85** | 914·9502 | 101·6600 | **94** | 1011·8273 | 112·4240 |
| **86** | 925·7143 | 102·8560 | **95** | 1022·5914 | 113·6200 |
| **87** | 936·4784 | 104·0520 | **96** | 1033·3555 | 114·8160 |
| **88** | 947·2426 | 105·2480 | **97** | 1044·1196 | 116·0120 |
| **89** | 958·0067 | 106·4440 | **98** | 1054·8838 | 117·2080 |
| **90** | 968·7708 | 107·6400 | **99** | 1065·6479 | 118·4040 |
| **91** | 979·5349 | 108·8360 | **100** | 1076·4120 | 119·6000 |

TABLE 61.—SQUARE FEET IN SQUARE METRES.

| Square Feet. | Square Metres. | Square Feet. | Square Metres. | Square Feet. | Square Metres. | Square Feet. | Square Metres. |
|---|---|---|---|---|---|---|---|
| **1** | ·0929 | **26** | 2·4154 | **51** | 4·7380 | **76** | 7·0605 |
| **2** | ·1858 | **27** | 2·5083 | **52** | 4·8309 | **77** | 7·1534 |
| **3** | ·2787 | **28** | 2·6012 | **53** | 4·9238 | **78** | 7·2463 |
| **4** | ·3716 | **29** | 2·6941 | **54** | 5·0167 | **79** | 7·3392 |
| **5** | ·4645 | **30** | 2·7870 | **55** | 5·1096 | **80** | 7·4321 |
| **6** | ·5574 | **31** | 2·8799 | **56** | 5·2025 | **81** | 7·5250 |
| **7** | ·6503 | **32** | 2·9728 | **57** | 5·2954 | **82** | 7·6179 |
| **8** | ·7432 | **33** | 3·0657 | **58** | 5·3883 | **83** | 7·7108 |
| **9** | ·8361 | **34** | 3·1586 | **59** | 5·4812 | **84** | 7·8037 |
| **10** | ·9290 | **35** | 3·2515 | **60** | 5·5741 | **85** | 7·8966 |
| **11** | 1·0219 | **36** | 3·3444 | **61** | 5·6670 | **86** | 7·9895 |
| **12** | 1·1148 | **37** | 3·4373 | **62** | 5·7599 | **87** | 8·0824 |
| **13** | 1·2077 | **38** | 3·5302 | **63** | 5·8528 | **88** | 8·1753 |
| **14** | 1·3006 | **39** | 3·6231 | **64** | 5·9457 | **89** | 8·2682 |
| **15** | 1·3935 | **40** | 3·7160 | **65** | 6·0386 | **90** | 8·3611 |
| **16** | 1·4864 | **41** | 3·8089 | **66** | 6·1315 | **91** | 8·4540 |
| **17** | 1·5793 | **42** | 3·9018 | **67** | 6·2244 | **92** | 8·5469 |
| **18** | 1·6722 | **43** | 3·9947 | **68** | 6·3173 | **93** | 8·6398 |
| **19** | 1·7651 | **44** | 4·0876 | **69** | 6·4102 | **94** | 8·7327 |
| **20** | 1·8580 | **45** | 4·1805 | **70** | 6·5031 | **95** | 8·8256 |
| **21** | 1·9509 | **46** | 4·2734 | **71** | 6·5960 | **96** | 8·9185 |
| **22** | 2·0438 | **47** | 4·3663 | **72** | 6·6889 | **97** | 9·0114 |
| **23** | 2·1367 | **48** | 4·4592 | **73** | 6·7818 | **98** | 9·1043 |
| **24** | 2·2296 | **49** | 4·5521 | **74** | 6·8747 | **99** | 9·1972 |
| **25** | 2·3225 | **50** | 4·6450 | **75** | 6·9676 | **100** | 9·2901 |

## TABLE 62.—SQUARE YARDS IN SQUARE METRES.

| Square Yards. | Square Metres. | Square Yards. | Square Metres. | Square Yards. | Square Metres. | Square Yards. | Square Metres. |
|---|---|---|---|---|---|---|---|
| **1** | ·8361 | **26** | 21·7389 | **51** | 42·6417 | **76** | 63·5445 |
| **2** | 1·6722 | **27** | 22·5750 | **52** | 43·4778 | **77** | 64·3806 |
| **3** | 2·5083 | **28** | 23·4111 | **53** | 44·3139 | **78** | 65·2167 |
| **4** | 3·3444 | **29** | 24·7472 | **54** | 45·1500 | **79** | 66·0528 |
| **5** | 4·1806 | **30** | 25·0834 | **55** | 45·9862 | **80** | 66·8890 |
| **6** | 5·0167 | **31** | 25·9195 | **56** | 46·8223 | **81** | 67·7251 |
| **7** | 5·8528 | **32** | 26·7556 | **57** | 47·6584 | **82** | 68·5612 |
| **8** | 6·6889 | **33** | 27·5917 | **58** | 48·4945 | **83** | 69·3973 |
| **9** | 7·5250 | **34** | 28·4278 | **59** | 49·3306 | **84** | 70·2334 |
| **10** | 8·3611 | **35** | 29·2639 | **60** | 50·1667 | **85** | 71·0695 |
| **11** | 9·1972 | **36** | 30·1000 | **61** | 51·0028 | **86** | 71·9056 |
| **12** | 10·0333 | **37** | 30·9361 | **62** | 51·8389 | **87** | 72·7417 |
| **13** | 10·8695 | **38** | 31·7723 | **63** | 52·6751 | **88** | 73·5779 |
| **14** | 11·7056 | **39** | 32·6084 | **64** | 53·5112 | **89** | 74·4140 |
| **15** | 12·5417 | **40** | 33·4445 | **65** | 54·3473 | **90** | 75·2501 |
| **16** | 13·3778 | **41** | 34·2806 | **66** | 55·1834 | **91** | 76·0862 |
| **17** | 14·2139 | **42** | 35·1167 | **67** | 56·0195 | **92** | 76·9223 |
| **18** | 15·0500 | **43** | 35·9528 | **68** | 56·8556 | **93** | 77·7584 |
| **19** | 15·8861 | **44** | 36·7889 | **69** | 57·6917 | **94** | 78·5945 |
| **20** | 16·7222 | **45** | 37·6250 | **70** | 58·5278 | **95** | 79·4306 |
| **21** | 17·5584 | **46** | 38·4612 | **71** | 59·3640 | **96** | 80·2668 |
| **22** | 18·3945 | **47** | 39·2973 | **72** | 60·2001 | **97** | 81·1029 |
| **23** | 19·2306 | **48** | 40·1334 | **73** | 61·0362 | **98** | 81·9390 |
| **24** | 20·0667 | **49** | 40·9695 | **74** | 61·8723 | **99** | 82·7751 |
| **25** | 20·9028 | **50** | 41·8056 | **75** | 62·7085 | **100** | 83·6112 |

## TABLE 63.—CUBIC METRES IN CUBIC FEET AND CUBIC YARDS.

| Cubic Metres. | Cubic Feet. | Cubic Yards. | Cubic Metres. | Cubic Feet. | Cubic Yards. |
|---|---|---|---|---|---|
| **1** | 35·3156 | 1·3080 | **10** | 353·1560 | 13·0800 |
| **2** | 70·6312 | 2·6160 | **11** | 388·4716 | 14·3880 |
| **3** | 105·9468 | 3·9240 | **12** | 423·7872 | 15·6960 |
| **4** | 141·2624 | 5·2320 | **13** | 459·1028 | 17·0040 |
| **5** | 176·5780 | 6·5400 | **14** | 494·4184 | 18·3120 |
| **6** | 211·8936 | 7·8480 | **15** | 529·7340 | 19·6200 |
| **7** | 247·2092 | 9·1560 | **16** | 565·0496 | 20·9280 |
| **8** | 282·5248 | 10·4640 | **17** | 600·3652 | 22·2360 |
| **9** | 317·8404 | 11·7720 | **18** | 635·6808 | 23·5440 |

TABLE 63.—CUBIC METRES IN CUBIC FEET AND CUBIC YARDS (*continued*).

| Cubic Metres. | Cubic Feet. | Cubic Yards. | Cubic Metres. | Cubic Feet. | Cubic Yards. |
|---|---|---|---|---|---|
| **19** | 670·9964 | 24·8520 | **60** | 2118·9360 | 78·4800 |
| **20** | 706·3120 | 26·1600 | **61** | 2154·2516 | 79·7880 |
| **21** | 741·6276 | 27·4680 | **62** | 2189·5672 | 81·0960 |
| **22** | 776·9432 | 28·7760 | **63** | 2224·8828 | 82·4040 |
| **23** | 812·2588 | 30·0840 | **64** | 2260·1984 | 83·7120 |
| **24** | 847·5744 | 31·3920 | **65** | 2295·5140 | 85·0200 |
| **25** | 882·8900 | 32·7000 | **66** | 2330·8296 | 86·3280 |
| **26** | 918·2056 | 34·0080 | **67** | 2366·1452 | 87·6360 |
| **27** | 953·5212 | 35·3160 | **68** | 2401·4608 | 88·9440 |
| **28** | 988·8368 | 36·6240 | **69** | 2436·7764 | 90·2520 |
| **29** | 1024·1524 | 37·9320 | **70** | 2472·0920 | 91·5600 |
| **30** | 1059·4680 | 39·2400 | **71** | 2507·4076 | 92·8680 |
| **31** | 1094·7836 | 40·5480 | **72** | 2542·7232 | 94·1760 |
| **32** | 1130·0992 | 41·8560 | **73** | 2578·0388 | 95·4840 |
| **33** | 1165·4148 | 43·1640 | **74** | 2613·3544 | 96·7920 |
| **34** | 1200·7304 | 44·4720 | **75** | 2648·6700 | 98·1000 |
| **35** | 1236·0460 | 45·7800 | **76** | 2683·9856 | 99·4080 |
| **36** | 1271·3616 | 47·0880 | **77** | 2719·3012 | 100·7160 |
| **37** | 1306·6772 | 48·3960 | **78** | 2754·6168 | 102·0240 |
| **38** | 1341·9928 | 49·7040 | **79** | 2789·9324 | 103·3320 |
| **39** | 1377·3084 | 51·0120 | **80** | 2825·2480 | 104·6400 |
| **40** | 1412·6240 | 52·3200 | **81** | 2860·5636 | 105·9480 |
| **41** | 1447·9396 | 53·6280 | **82** | 2895·8792 | 107·2560 |
| **42** | 1483·2552 | 54·9360 | **83** | 2931·1948 | 108·5640 |
| **43** | 1518·5708 | 56·2440 | **84** | 2966·5104 | 109·8720 |
| **44** | 1553·8864 | 57·5520 | **85** | 3001·8260 | 111·1800 |
| **45** | 1589·2020 | 58·8600 | **86** | 3037·1416 | 112·4880 |
| **46** | 1624·5176 | 60·1680 | **87** | 3072·4572 | 113·7960 |
| **47** | 1659·8332 | 61·4760 | **88** | 3107·7728 | 115·1040 |
| **48** | 1695·1488 | 62·7840 | **89** | 3143·0884 | 116·4120 |
| **49** | 1730·4644 | 64·0920 | **90** | 3178·4040 | 117·7200 |
| **50** | 1765·7800 | 65·4000 | **91** | 3213·7196 | 119·0280 |
| **51** | 1801·0956 | 66·7080 | **92** | 3249·0352 | 120·3360 |
| **52** | 1836·4112 | 68·0160 | **93** | 3284·3508 | 121·6440 |
| **53** | 1871·7268 | 69·3240 | **94** | 3319·6664 | 122·9520 |
| **54** | 1907·0424 | 70·6320 | **95** | 3354·9820 | 124·2600 |
| **55** | 1942·3580 | 71·9400 | **96** | 3390·2976 | 125·5680 |
| **56** | 1977·6736 | 73·2480 | **97** | 3425·6132 | 126·8760 |
| **57** | 2012·9892 | 74·5560 | **98** | 3460·9288 | 128·1840 |
| **58** | 2048·3048 | 75·8640 | **99** | 3496·2444 | 129·4920 |
| **59** | 2083·6204 | 77·1720 | **100** | 3531·5600 | 130·8000 |

## TABLE 64.—CUBIC FEET IN CUBIC METRES.

| Cubic Feet. | Cubic Metres. | Cubic Feet. | Cubic Metres. | Cubic Feet. | Cubic Metres. | Cubic Feet. | Cubic Metres. |
|---|---|---|---|---|---|---|---|
| **1** | ·0283 | **26** | ·7362 | **51** | 1·4450 | **76** | 2·1519 |
| **2** | ·0566 | **27** | ·7645 | **52** | 1·4724 | **77** | 2·1803 |
| **3** | ·0849 | **28** | ·7928 | **53** | 1·5007 | **78** | 2·2086 |
| **4** | ·1133 | **29** | ·8211 | **54** | 1·5290 | **79** | 2·2369 |
| **5** | ·1416 | **30** | ·8494 | **55** | 1·5573 | **80** | 2·2652 |
| **6** | ·1699 | **31** | ·8778 | **56** | 1·5856 | **81** | 2·2935 |
| **7** | ·1982 | **32** | ·9061 | **57** | 1·6140 | **82** | 2·3218 |
| **8** | ·2265 | **33** | ·9344 | **58** | 1·6423 | **83** | 2·3501 |
| **9** | ·2548 | **34** | ·9627 | **59** | 1·6706 | **84** | 2·3785 |
| **10** | ·2831 | **35** | ·9910 | **60** | 1·6989 | **85** | 2·4068 |
| **11** | ·3115 | **36** | 1·0193 | **61** | 1·7272 | **86** | 2·4351 |
| **12** | ·3398 | **37** | 1·0477 | **62** | 1·7555 | **87** | 2·4634 |
| **13** | ·3681 | **38** | 1·0760 | **63** | 1·7838 | **88** | 2·4917 |
| **14** | ·3964 | **39** | 1·1043 | **64** | 1·8122 | **89** | 2·5200 |
| **15** | ·4247 | **40** | 1·1326 | **65** | 1·8405 | **90** | 2·5483 |
| **16** | ·4530 | **41** | 1·1609 | **66** | 1·8688 | **91** | 2·5767 |
| **17** | ·4814 | **42** | 1·1892 | **67** | 1·8971 | **92** | 2·6050 |
| **18** | ·5097 | **43** | 1·2175 | **68** | 1·9254 | **93** | 2·6333 |
| **19** | ·5380 | **44** | 1·2459 | **69** | 1·9537 | **94** | 2·6616 |
| **20** | ·5663 | **45** | 1·2742 | **70** | 1·9820 | **95** | 2·6899 |
| **21** | ·5946 | **46** | 1·3025 | **71** | 2·0104 | **96** | 2·7182 |
| **22** | ·6229 | **47** | 1·3308 | **72** | 2·0387 | **97** | 2·7466 |
| **23** | ·6512 | **48** | 1·3591 | **73** | 2·0670 | **98** | 2·7749 |
| **24** | ·6795 | **49** | 1·3874 | **74** | 2·0953 | **99** | 2·8032 |
| **25** | ·7079 | **50** | 1·41570 | **75** | 2·1236 | **100** | 2·8315 |

## TABLE 65.—CUBIC YARDS IN CUBIC METRES.

| Cubic Yards. | Cubic Metres. | Cubic Yards. | Cubic Metres. | Cubic Yards. | Cubic Metres. | Cubic Yards. | Cubic Metres. |
|---|---|---|---|---|---|---|---|
| **1** | ·7645 | **11** | 8·4096 | **21** | 16·0548 | **31** | 23·6999 |
| **2** | 1·5290 | **12** | 9·1742 | **22** | 16·8193 | **32** | 24·4644 |
| **3** | 2·2935 | **13** | 9·9387 | **23** | 17·5838 | **33** | 25·2289 |
| **4** | 3·0581 | **14** | 10·7032 | **24** | 18·3483 | **34** | 25·9934 |
| **5** | 3·8226 | **15** | 11·4677 | **25** | 19·1128 | **35** | 26·7580 |
| **6** | 4·5871 | **16** | 12·2322 | **26** | 19·8773 | **36** | 27·5225 |
| **7** | 5·3516 | **17** | 12·9967 | **27** | 20·6419 | **37** | 28·2870 |
| **8** | 6·1161 | **18** | 13·7612 | **28** | 21·4064 | **38** | 29·0515 |
| **9** | 6·8806 | **19** | 14·5257 | **29** | 22·1709 | **39** | 29·8160 |
| [illegible] | 7·6451 | **20** | 15·2903 | **30** | 22·9354 | **40** | 30·5805 |

TABLE 65.—CUBIC YARDS IN CUBIC METRES (*continued*).

| Cubic Yards. | Cubic Metres. | Cubic Yards. | Cubic Metres. | Cubic Yards. | Cubic Metres. | Cubic Yards. | Cubic Metres. |
|---|---|---|---|---|---|---|---|
| **41** | 31·3450 | **56** | 42·8127 | **71** | 54·2804 | **86** | 65·7481 |
| **42** | 32·1095 | **57** | 43·5772 | **72** | 55·0449 | **87** | 66·5126 |
| **43** | 32·8741 | **58** | 44·3418 | **73** | 55·8094 | **88** | 67·2771 |
| **44** | 33·6386 | **59** | 45·1063 | **74** | 56·5740 | **89** | 68·0417 |
| **45** | 34·4031 | **60** | 45·8708 | **75** | 57·3385 | **90** | 68·8062 |
| **46** | 35·1676 | **61** | 46·6353 | **76** | 58·1030 | **91** | 69·5707 |
| **47** | 35·9321 | **62** | 47·3998 | **77** | 58·8675 | **92** | 70·3352 |
| **48** | 36·6966 | **63** | 48·1643 | **78** | 59·6320 | **93** | 71·0997 |
| **49** | 37·4611 | **64** | 48·9288 | **79** | 60·3965 | **94** | 71·8642 |
| **50** | 38·2256 | **65** | 49·6933 | **80** | 61·1610 | **95** | 72·6287 |
| **51** | 38·9902 | **66** | 50·4579 | **81** | 61·9256 | **96** | 73·3932 |
| **52** | 39·7547 | **67** | 51·2224 | **82** | 62·6901 | **97** | 74·1578 |
| **53** | 40·5192 | **68** | 51·9869 | **83** | 63·4546 | **98** | 74·9223 |
| **54** | 41·2837 | **69** | 52·7514 | **84** | 64·2191 | **99** | 75·6868 |
| **55** | 42·0482 | **70** | 53·5159 | **85** | 64·9836 | **100** | 76·4513 |

TABLE 66.—APPROXIMATE EQUIVALENTS OF FRENCH AND ENGLISH MEASURES.

| | |
|---|---|
| 1 chain (22 yards) . . | 20 metres (exactly 20·1166 metres). |
| 5 furlongs . . . . | 1 kilometre (exactly 1·0058 kilometres). |
| 1 foot . . . . | 3 decimetres (exactly 3·048 decimetres).<br>30 centimetres. |
| 1 metre . . . . | 3·28 feet.<br>3 feet 3 inches $\frac{3}{8}$ inch ($\frac{1}{512}$ inch less).<br>40 inches (1·6 per cent. less). |
| 1 inch . . . . . | 25 millimetres (exactly 25·4). |
| 1 yard . . . . . | $\frac{11}{12}$ metre. |
| 11 metres . . . . | 12 yards. |
| To convert metres into yards . . . . | Add $\frac{1}{11}$th. |
| 1 kilometre . . . . | $\frac{5}{8}$ mile. |
| 1 mile . . . . . | 1·6 or $1\frac{3}{5}$ kilometres. |
| 1 square inch . . . | 6·5 square centimetres. |
| 1 square metre . . . | $10\frac{3}{4}$ square feet.<br>$1\frac{1}{5}$ square yards. |
| 1 square yard . . . | $\frac{5}{6}$ square metre. |
| 1 acre . . . . | 4000 square metres (1·2 per cent. more). |
| 1 square mile . . . | 260 hectares (0·4 per cent. less). |

M

| | |
|---|---|
| 1 cubic yard . . . . | $\frac{3}{4}$ cubic metre (2 per cent. more). |
| 1 cubic metre . . | $1\frac{1}{3}$ cubic yard ($1\frac{2}{3}$ per cent. less). |
| 1 cubic metre . . . . | $35\frac{1}{3}$ cubic feet (·05 per cent. less). |
| 1 litre . . . . . | $1\frac{3}{4}$ pints fully. |
| 1 gallon . . . . . | $4\frac{1}{2}$ litres fully. |
| 1 cubic foot . . . | 28·3 litres. |
| 1 cubic metre of water . | 1 ton nearly. |
| 1 gramme . . . | $15\frac{1}{2}$ grains nearly. |
| 1 kilogramme . . . . | 2·2 pounds fully. |
| 1000 kilogrammes / 1 metric ton . | 1 ton nearly. |
| 1 hundredweight . . | 51 kilogrammes nearly. |

### Table 67.—French and English Compound Equivalents.

| | |
|---|---|
| 1 kilogramme per lineal metre . . . . | ·672 pound per lineal foot.<br>2·016 pounds per yard. |
| 1000 kilogrammes (1 tonne) per metre . . . . | ·300 ton per foot. |
| 1 kilogramme per kilometre . | 3·548 pounds per mile. |
| 1000 kilogrammes (1 tonne) per kilometre . . . | 1·584 tons per mile. |
| 1 kilogramme per square millimetre . . . . | 1422·32 pounds per square inch.<br>·635 ton per square inch. |
| 1 kilogramme per square centimetre . . . . | 14·2232 pounds per square inch. |
| 1 kilogramme per square decimetre . . . . | 20·4776 pounds per square foot. |
| 1 kilogramme per square metre . . . . . | 1·8430 pounds per square yard. |
| 1000 kilogrammes (1 tonne) per square metre . . | ·8229 ton per square yard. |
| 1 kilogramme per tonne . . | 2·240 pounds per ton. |
| 1 kilogramme per tonne per. kilometre . . . . | 3·6042 pounds per ton per mile. |
| 1 litre of water at 4° C. per tonne per kilometre . | 3·6042 pounds per ton per mile.<br>·3599 gallon at 62° F. per ton per mile. |
| 1 gramme per square millimetre . . . . . . | 1·422 pounds per square inch. |
| 1 gramme per square centimetre . . . . . | ·01422 pound per square inch. |
| 1 kilogramme per cubic metre | 1·686 pounds per cubic yard.<br>·0624 pound per cubic foot. |
| 1000 kilogrammes (1 tonne) per cubic metre . . . | ·984 ton per cubic metre.<br>·752 ton per cubic yard. |

| | |
|---|---|
| 1 cubic metre per kilogramme | 16·019 cubic feet per pound. |
| 1 cubic metre per tonne . | 1·329 cubic yards per ton.<br>35·882 cubic feet per ton. |
| 1 cubic metre per kilometre . | 2·105 cubic yards per mile. |
| 1 gramme per litre . . | 73·09 grains per gallon. |
| 1 kilogramme per litre . . | 10·4382 pounds per gallon. |
| 1 cubic metre per lineal metre | 1·196 cubic yards per lineal yard. |
| 1 cubic metre per square metre | 3·281 cubic feet per square foot. |
| 1 litre per square metre . . | ·0204 gallon per square foot. |
| 1 cubic metre per hectare . | ·405 cubic metre per acre.<br>·529 cubic yard per acre.<br>89·065 gallons per acre. |
| 1 kilogrammetre . . . . | 7·233 foot-pounds. |
| 1 tonne-metre . . . . | 3 foot-tons. |
| 1 cheval vapeur, or cheval (75k × m per second) . . | ·9863 horse-power. |
| 1 kilogramme per cheval . | 2·235 pounds per horse-power. |
| 1 square metre per cheval . | 10·913 square feet per horse-power. |
| 1 cubic metre per cheval . | 35·806 cubic feet per horse-power. |
| 1 calorie or French unit of heat . . . . . . | 3·968 English heat-units. |
| French mechanical equivalent of heat (425 kilogrammetres) . . . . . | 3074 foot-pounds per unit. |
| 1 calorie per square metre . | ·369 heat-unit per square foot. |
| 1 calorie per kilogramme . | 1·800 heat-units per pound. |
| 1 franc per kilogramme . . | ·360 shillings per pound.<br>£40·32 per ton. |
| 1 franc per quintal . . | ·403 shillings per cwt. |
| 1 franc per tonne . . . | ·484 penny per cwt.<br>·806 shilling per ton. |
| 1 franc per metre . . . | ·726 shilling per yard.<br>8·709 pence per yard. |
| 1 franc per kilometre . . | £·06386 per mile.<br>15·326 pence per mile. |
| 1 franc per square metre . | 7·963 pence per square yard.<br>·6636 shilling per square yard. |
| 1 franc per cubic metre . | 7·281 pence per cubic yard. |
| 1 franc per litre . . . | 3·606 shillings per gallon. |
| 1 franc per hectolitre . . | 1·893 shillings per hogshead. |

TABLE 68.—ENGLISH AND FRENCH COMPOUND EQUIVALENTS.

| | |
|---|---|
| 1 pound per lineal foot | 1·488 kilogrammes per lineal metre. |
| 1 pound per yard | ·496 kilogramme per metre. |
| 1 ton per foot | 3333·333 kilogrammes ($3\frac{1}{3}$ tons) per metre. |
| 1 ton per yard | 1111·111 kilogrammes ($1\frac{1}{9}$ tons) per metre. |
| 1 pound per mile | ·2818 kilogrammes per kilometre. |
| 1 ton per mile | ·6313 tonne per kilometre. |
| 1 pound per ton | ·4464 kilogramme per tonne. |
| 1 pound per ton per mile | ·2774 kilogramme per tonne per kilometre. |
| 1 pound per square inch | ·0703077 kilogramme per square centimetre.<br>·7031 gramme per square millimetre.<br>5·170 centimetres of mercury at 0° C. |
| 1 atmosphere (14·7 pounds per square inch) | 1·0335 kilogrammes per square centimetre. |
| 1000 pounds per square inch | ·703077 kilogramme per square millimetre. |
| 2000 pounds per square inch | 1·406154 kilogrammes per square millimetre. |
| 1 ton per square inch | 1·575 kilogrammes per square millimetre. |
| 1 pound per square foot | 4·883 kilogrammes per square metre. |
| 1000 pounds per square foot | 4882·517 kilogrammes per square metre. |
| 1 ton per square foot | 10·936 tonnes per square metre. |
| 1000 pounds per square yard | 542·500 kilogrammes per square metre. |
| 1 ton per square yard | 1·215 tonnes per square metre. |
| 1 pound per cubic yard | ·5933 kilogramme per cubic metre. |
| 1 pound per cubic foot | 16·020 kilogrammes per cubic metre. |
| 1 ton per cubic yard | 1·329 tonnes per cubic metre. |
| 1 cubic yard per pound | 1·6855 cubic metres per kilogramme. |
| 1 cubic yard per ton | ·7525 cubic metre per tonne. |
| 1 cubic yard per mile | ·4750 cubic metre per kilometre. |

| | |
|---|---|
| 1 grain per gallon | ·01426 gramme per litre. |
| 1 pound per gallon | ·09983 kilogramme per litre. |
| 1 cubic yard per lineal yard | ·836 cubic metre per lineal metre. |
| 1 cubic foot per square foot | 3·048 cubic metres per square metre. |
| 1 gallon per square foot | 48·905 litres per square metre. |
| 1 cubic metre per acre | 2·471 cubic metres per hectare. |
| 1 cubic yard per acre | 1·902 cubic metres per hectare. |
| 1000 gallons per acre | 11·226 cubic metres per hectare. |
| 1 foot-pound | ·1382 kilogrammetre. |
| 1 foot-ton | ·3333 tonne-metre. |
| 1 horse-power | 1·0139 cheval. |
| 1 pound per horse-power | ·447 kilogramme per cheval. |
| 1 square foot per horse-power | ·0196 square metre per cheval. |
| 1 cubic foot per horse-power | ·0279 cubic metre per cheval. |
| 1 English unit of heat, or heat-unit | ·252 calorie. |
| English mechanical equivalent to one heat-unit (772 foot-pounds) | 10·67 kilogrammetres. |
| 1 English heat-unit per square foot | 2·713 calories per square metre. |
| 1 English heat-unit per pound | $\frac{5}{9}$ calorie per kilogramme. |
| 1 penny per pound | ·231 franc per kilogramme. |
| 1 shilling per pound | 2·772 franc per kilogramme. |
| 1 shilling per cent., or £1 per ton | 24·802 francs per tonne. 2·48 francs per quintal. |
| 1 shilling per yard | 1·378 francs per metre. |
| 1 penny per mile | ·0652 franc per kilometre. |
| £1 per mile | 15·660 francs per kilometre. |
| 1 shilling per square yard | 1·510 francs per square metre. |
| £1 per square yard | 30·194 francs per square metre. |
| 1 penny per cubic foot | 3·708 francs per cubic metre. |
| 1 penny per cubic yard | ·137 franc per cubic metre. |
| 1 shilling per cubic yard | 1·648 francs per cubic metre. |
| £1 per cubic yard | 32·962 francs per cubic metre. |
| 1 shilling per hogshead | ·528 franc per hectolitre. |
| 1 penny per gallon | ·0231 franc per litre. |

## EUROPE.

### Austria-Hungary.

*Length.* 1 Fuss = 1·0371 feet ; 2 Fuss = 1 Elle = 2·0742 feet ; 6 Fuss = 1 Klafter = 6·2226 feet ; 4000 Klafter = 1 Meile = 4·714 miles.

*Surface.* 1 square Klafter = 38·7225 square feet = 4·3025 square yards; 1600 square Klafter = 1 Joch = 1·4223 acres.

*Volume.* 1 cubic Klafter = 240·94 cubic feet = 8·924 cubic yards.

*Capacity, dry.* 1 Achtel = 1·6920 gallons; 2 Achtel = 1 Viertel = 3·3840 gallons = ·4230 bushel; 4 Viertel = 1 Metze = 1·6918 bushels.

*Capacity, liquid.* 1 Kanne = 1·2457 pints; 2 Kannen = 1 Mass = 1·2457 quarts; 10 Mass = 1 Viertel = 3·1143 gallons; 4 Viertel = 1 Eimer = 12·4572 gallons.

*Weight.* 1 Pfund = 1·2347 pounds; 100 Pfund = 1 Centner = 123·47 pounds = 1·1024 hundredweights.

The French metric system of weights and measures is legal in Austria-Hungary.

### Belgium.

The French metric system is in force in Belgium. The name *aune* is substituted for metre, *litron* for litre, *livre* for kilogramme.

### Denmark.

*Length.* 1 Fod = 1·0297 feet; 6 Fod = 1 Favn = 6·1783 feet; 1 Mil = 4·68055 miles.

*Surface.* 1 square Fod = 1·0603 square feet; 144 square Fod = 1 square Rode = 16·966 square yards.

*Volume.* 1 cubic Fod = 1·0918 cubic feet. The Favn of firewood = 6 Fod × 6 Fod × 2 Fod = 72 cubic Fod = 78·60 cubic feet.

*Capacity, liquid.* 38 Potter = 1 Anker = 8·0709 gallons; 136 Potter = 1 Tönde = 28·885 gallons.

*Capacity, dry.* 1 Tönde or barrel of grain or salt = 3·8231 bushels; barrel of coal = 4·7 bushels.

*Weight.* 100 Kvinten = 1 Pund = 1·1023 pounds; 100 Pund = 1 Centner = 110·23 pounds; 40 Centner = 1 Last = 1·9684 tons; 1 Skip-last = 2·5590 tons.

### Germany.

The French metrical system of weights and measures came nto force in Germany, on January 1, 1872.

*Length.* The metre is known as the *Stab;* the centimetre, the *Neu-Zoll;* the kilometre is the same; 7 kilometres = 1 mile = 4·35 English miles.

*Surface.* The square metre is the *Quadrat-stab;* the are is the *Ar;* the hectare is the *Hectar.* The square kilometre is the *Quadrat* = 247·11 acres.

*Volume.* 2 Schoppens = 1 Kanne = 1 litre; 50 kannes = 1 scheffel = 50 litres = 1·376 bushels; 2 scheffels = 1 Fass (cask) = 1 hectolitre = 22·01 gallons.

*Weight.* The milligramme, centigramme, and decigramme

are respectively the *Milligram*, *Centigramm*, and *Dezigramm*. 100 dezigramms = 1 Neu-loth = 10 grammes = ·35273 ounce; 50 neu-loths = 1 Pfund = ½ kilogramme = 1·1023 pounds; 100 pfunds = 1 Centner = 50 kilogrammes = 110·23 pounds; 20 centners = 1 tonne = 2204·6 pounds or ·9842 ton.

### Greece.

The French metric system is employed in Greece. The metre is the *pecheus*, the kilometre the *stadion*, the are the *stremma;* the litre the *litra*, the gramme the *drachmé*. 1½ kilogrammes = 1 Mnâ; 1½ quintals = 1 tolanton; 1½ tonneaux = 1 Tono = 29·526 hundredwt.

### Italy.

The French metric system is in force. The metre is known as the *metro;* the kilometre, *chilometro;* the are, *aro;* the hectare, *ettaro;* the litre, *litro;* the gramme, *gramo;* the tonne, *tonnellata*.

### Netherlands.

The French metric system is in force in the Netherlands. The French nomenclature is followed, with but trifling variations.

### Portugal.

The French metric system is the legal standard. The old measures principally still in use are: the libra = 1·012 pounds; the almude of Lisbon = 3·7 gallons; the almude of Oporto = 5·6 gallons; the alquiere = ·36 bushel; the moio = 2·78 quarters.

### Roumania.

The French metric system is in force in Roumania. Turkish weights and measures are largely in use by the people.

### Russia.

*Length.* 1 Vershok = 1·75 inches; 16 Vershoks = 1 Arschine = 28 inches; 3 Arschines = 1 Sajene = 7 feet; 500 Sajenes = 1 Verst = 3,500 feet or ·6629 mile. The English foot decimally divided is the ordinary standard of length. The Rhein Fuss (= 1·03 English feet) is used in calculating export duties on timber.

*Surface.* 1 square Arschine = 5·444 square feet; 9 square arschines = 1 square sajeen = 49 square feet; 2,400 square sajeens = 1 Desatine = 2·70 acres. For earthworks, masonry, &c., the sajene is divided into tenths (dessiatka), hundredths (Sotka), and thousandths (tisiatchka). These are squared and cubed, for superficial and cubic measurements.

*Capacity, liquid.* 1 Tscharkey = ·2164 pint; 10 tscharkeys = 1 Krushka = 1·0820 quarts; 100 tscharkeys = 1 Vedro = 2·7049 gallons; 3 vedros = 1 anker = 8·1147 gallons; 40 Vedros = 1 Sarokowaja Boshka = 108·196 gallons.

*Capacity, dry.* (Grain.) 1 Tschetwert = 5·7704 bushels (usually reckoned at 5¾ bushels); 16 Tschetwerts = 1 Last = 11·5408 quarters. 100 Tschetwerts are usually reckoned equal to 72 quarters; they are exactly 72·1308 quarters.

*Weight.* 12 lanas = 32 lottis = 96 Zolotnicks = 1 Funt or pound = ·90285 English pound = 14·446 ounces; 40 pounds = 1 Pood = 36·114 English pounds; 62·0257 Poods = 1 English ton; 1 ship-last = 1·89 English tons.

## Servia.

The French metric system has been in use in Servia since 1883. The old Turkish and Austrian weights and measures still linger in outlying districts.

## Spain.

The French metric system has been established in Spain since 1859. The metre is the *metro;* the litre, the *litro;* the gramme the *gramo;* the are, the *area.* The old system continues largely in use.

*Length.* 12 lineas = 1 pulgada = ·927 inch; 12 pulgadas = 1 Pies de Burgos = ·9273 foot; 3 Pies = 1 Vara = 2·782 feet; 5,000 Varas = 1 Legua (Castilian) = 2·6345 miles; 8,000 Varas = 1 Legua (Spanish) = 4·2151 miles.

*Surface.* 1 square Vara = ·860 square yard; 16 square Varas = 1 square Estadal = 13·759 square yards; 576 square Estadals = 1 Fanegada = 1·6374 acres.

*Capacity, liquid.* 4 Cuartillas = 1 Arroba Mayor (for wine) = 3·552 gallons; 1 Arroba Menor (for oil), 2·7652 gallons.

*Capacity, dry.* 12 Amuerzas = 1 Fanega = 1·5077 bushels.

*Weight.* 8 Octavos = 1 Onza = 1·0144 ounces; 16 Onzas = 1 Libra = 1·0144 pounds; 100 Libras = 1 Quintal = 101·442 pounds; 10 Quintals = 1 Tonelada = 1014·42 pounds.

## Sweden.

The French metric system became obligatory in Sweden in 1889. The following are measures according to the system formerly in use.

*Length.* 10 Tumer = 1 Fot = 11·6892 inches; 10 Fot = 1 Stang = 9·7411 feet; 10 Stanger = 1 Ref = 32·4703 yards; 360 Ref = 1 Meile = 6·6417 miles.

*Surface.* 100 square Tumer = 1 square Fot = ·9489 square

foot; 1 square Ref = ·2178 acre; 5·6 square Ref = 1 Tunnland = 1·2198 acres.

### Switzerland.

The French metric system has been generally adopted in Switzerland, with some changes of names, and of subdivisions.

*Length.* 10 Zoll = 1 Fuss (3 decimetres) = 11·811 inches; 6 Fuss = 1 Klafter = 5·9056 feet; 10 Fuss = 1 Ruthe = 9·8427 feet; 1600 Ruthen = 1 Lien = 2·9826 miles.

*Surface.* 100 square Fuss = 1 square Ruthe = 10·7643 square yards; 400 square Ruthen = 1 Juchart = ·8694 acre; 6400 Jucharten = 1 square Stunde = 5693·52 acres.

*Volume.* 1000 cubic Zoll = 1 cubic Fuss = ·9535 cubic foot; 1000 cubic Fuss = 1 cubic Ruthe = 35·3166 cubic yards.

*Weight.* 16 Unzen = 1 Pfund (½ kilogramme) = 1·1023 pounds; 100 Pfund = 1 Centner = 110·233 pounds = ·9842 hundredweight. The Pfund is legally divided into 500 grammes; but the people generally prefer the divisions into halves, quarters, and eighths.

### Turkey.

*Length.* 1 pike, or drâ, or Andazé (cloth measure) = 27 inches, divided in 24 Kerâts. The Archin (land measure) = 30 inches; 1 Forsang = 3·116 miles divided into 3 Berri; Surveyor's Pik, or the Halebi = 27·9 inches; 5½ Halebis = 1 reed.

*Surface.* The squares of the Kerât, the Pike, and the Reed. The Feddan is an area of land equal to as much as a yoke of oxen can plough in a day.

*Capacity, dry.* 900 Dirhems = 1 Rottol = 1·411 quarts; 22 Rottols = 1 Kileh = 7·762 gallons, or ·97 bushels; the chief measure for grain, 100 Kilehs = 12·128 imperial quarters.

*Capacity, liquid.* 1 Almud = 1·152 gallons; 1 Rottol = 2·5134 pints; 100 Rottols = 1 Cantar = 31·417 gallons.

*Weight.* The Oke = 2·8342 pounds; 100 Rottolos = 1 Cantar = 124·704 pounds.

### Malta.

*Length.* 3½ palmi = 1 yard; 1 Canna = 2$\frac{2}{7}$ yards.

*Surface.* 1 Salma = 4·964 acres. Approximately, 543 square palmi = 400 square feet; 16 Salmi = 71 acres.

*Volume.* 1 cubic Tratto = 8 cubic feet; 1 cubic Canna = 343 cubic feet.

*Weight.* 15 Oncie = 14 ounces; 1 Rotolo = 1¾ pounds; 64 Rotoli = 1 hundredwt.; 1 Cantaro = 175 pounds; 1 Quintal = 199 pounds; 64 Cantari = 5 tons.

The weights and measures of Turkey, England, and France, are all in use. The principal units are:—

1 Cantaro = 44 oche = 121·0 pounds (English).
1 Oca = 400 dramme = 2·75 pounds.
1 Dramma = 48·15 grains.
1 Picco = 2·296 feet.
1 Scala = 1914·4 square yards.

### Candia.

The Pic = 25·11 inches; the Carga (corn) = 4·19 bushels; the Rotolo = 1·165 pounds; 100 Rotolos = 1 Cantaro = 116·5 pounds; the Okka = 2·65 pounds.

## ASIA.

### Burmah.

The British yard, foot, and inch are in use in Burmah; also the British measures of capacity.

The toung or cubit of 3 maik or span = 19½ inches; 4 toung = 1 lan (fathom); 7 toung = 1 ta; 1000 ta = 1 taing, nearly two English miles.

Measures of capacity depend upon the teng or basket, the value of which varies for different localities: holding from 23 pounds to 50 pounds of rice. An endeavour has been made to introduce a standard basket, containing 2218·19 cubic inches, not as yet successfully.

1 Kyat = 252 grains; 100 Kyats = 1 Piet-tha = 3·652 pounds avoirdupois.

### Ceylon.

The weights and measures of Ceylon are the same as those of the United Kingdom. There are also the Seer = 1·86 pints; 10 parrahs = 1 Amomam = 5·6 bushels.

### China.

The Chih of 14·10 English inches is the legal standard in the tariff settled by treaty between Great Britain and China. It is the only authorised measure of length at all the ports of trade. The Fên = ·141 inch; the Tsun = 1·41 inches; 10 Chih = 1 Cháng = 11·75 feet; 10 Cháng = 1 Yin = 39·17 yards. At Canton there are four different values of the chih; at Pekin, there are thirteen different chihs.

*Surface.* 25 square Chih = 1 Kung = 3·36 square yards; 240 Kung = 1 Mou = 806¾ square yards; 100 Mou = 1 King = 16⅔ acres. The Mou is the chief land measure.

*Capacity.* The Tou = 2½ gallons.

*Weight.* The Tael $=1\frac{1}{3}$ ounces; the Katty $=1\frac{1}{3}$ pounds; the Picul $=133\frac{1}{3}$ pounds.

### Cochin China.

The Thuoe, or Cubit, 19·2 inches, is the principal unit of length; but it varies for different places. The Li is 486 yards; 10 Li = 1 league = 2·761 miles. 9 square Ngu = 1 square Saö = 64 square yards; 100 square Saö = 1 square Maö = 1·32 acres. 1 Ai = ·0000006 grain; 1 Nen = ·8594 pound; 1 Quan $=687\frac{1}{2}$ pounds; 1 Hao (grain) $=6\frac{2}{9}$ gallons.

### Dutch East Indies—Java.

The legal weights and measures of Dutch India are those of the Netherlands. In Java, other measures are in common use. The Duim = 1·3 inches; the Ell = 27·08 inches. The Djong of 4 Bahu = 7·015 acres. Measures of capacity are taken by definite weight: 1 Sack = 61·034 pounds; 2 Sacks = 1 Pecul = 122·068 pounds. For liquids, the Kan = ·328 gallon; the Leager = 127·34 gallons. For weights, the Tael = 1·36 ounces; the Pecul = 135·63 pounds.

### Hong Kong.

The British weights and measures are in general use in Hong Hong. There are also the Tael $=1\frac{1}{3}$ ounces; the Picul = 133 pounds; the Catty $=1\frac{3}{4}$ pounds; the Chek $=14\frac{5}{8}$ inches; the Cheung $=12\frac{3}{16}$ feet.

### India—Bengal.

*Length.* 1 Jow, or Jaub $=\frac{1}{4}$ inch; 1 Guz = 1 yard; 1 Coss = 2000 yards, or 1·1364 miles. But the Coss varies from 1 mile to 2 miles in different districts. In the Punjab it is generally 2 miles.

*Surface.* 4 square Hât'hs = 1 Cowrie = 1 square yard; 1 Beegah = 1600 square yards, or ·3306 acre. For Government surveys, the following table is used:—

| | | |
|---|---|---|
| | 1 Guz . . . | 33 lineal inches. |
| 3 Guz . . . | 1 Baus, or Rod . . | $8\frac{1}{4}$ lineal feet. |
| 9 Square Guz . . | 1 Square Baus . | $68\frac{1}{16}$ square feet. |
| 400 Square Baus . | 1 Beegah . . . | 3025 square yards, ·625 acre. |

*Capacity.* The Seer is taken at 68 cubic inches, or 1·962 pints. But it varies. 5 Seer = 1 Palli; 40 Seer = 1 Maund = 9·81 gallons. The Sooli = 3·065 bushels.

*Weight.* The Tola = 180 grains, the weight of a rupee, is the unit of weight; 5 Tolas = 1 Chittâk; 80 Tolas = 1 Seer = 2·057 pounds; 40 Seers = 1 Maund = 82·286 pounds.

**India—Bombay.**

The Tussoo = $1\frac{1}{8}$ inches; 16 Tussoos = 1 Hat'h = 18 inches; 24 Tussoos = 1 Guz = 27 inches. The Builder's Tussoo = 2·3625 inches in Bombay; and 1 inch in Surat.

*Surface.* The Kutty = 9·8175 square yards; 20 Kutty = 1 Pund = 196·35 square yards; 20 Pund = 1 Beegah = ·8114 acre. In the Revenue Field Survey the English acre is used.

*Capacity.* The Seer = ·56 pint; 4 Seers = 1 Pylee = 2·2401 pints; 16 Pylees = 1 Parah = 4·4802 gallons; 8 Parahs = 1 Candy = 35·8415 gallons; 25 Parahs = 112·0045 gallons. In timber measurement in Bombay Dockyards, a Covit or Candy = 12·704 cubic feet.

*Weight.* 1 Seer = 11·2 ounces, 1 Maund = 28 pounds; 1 Candy = 5 cwt.

According to an Act passed in 1871, the primary standard of weight is a *Ser*, equal in weight to one kilogramme = 2·205 pounds avoirdupois. For capacity, the litre is the Standard. The divisions to be decimal.

**India—Madras.**

The British foot and yard are in use. The Guz = 33 inches; the Baum or Fathom is about $6\frac{1}{2}$ feet. The Nalli-Valli is a little less than $1\frac{1}{2}$ miles; 7 Nalli-Valli = 1 Kâdam, or about 10 miles.

1 Span = 8 inches; 1 Cubit = 18 inches: 8000 Cubits = 1 Cos = 2·27 miles.

*Surface.* 1 Coolie = 64 square yards; 100 Coolies = 1 Cawnie = 1·3223 acres.

*Capacity.* 8 Ollucks = 1 Puddee = 1·442 quarts; 8 Puddees = 1 Mercâl = 2·885 gallons; 5 Mercâls = 1 Parah = 14·426 gallons; 80 Parahs = 1 Garee = 18·033 quarters. These measures of capacity, though legal, are not commonly used. The "Customary" Puddee, in general use, has, when slightly heaped, a capacity of 1·504 quarts. The Seer measure is the most common, measuring from $66\frac{1}{2}$ to 67 cubic inches.

*Weight.* The Tola = 180 grains; 3 Tolas = 1 Pollum = 1·234 ounces; 8 Pollums = 1 Seer = 9·874 ounces; 5 Seers = 1 Viss = 3·086 pounds; 8 Viss = 1 Maund = 24·686 pounds; 20 Maunds = 1 Candy = 4·480 hundredwts. The Vis is usually reckoned as $3\frac{1}{4}$ pounds; the Maund as 25 pounds; the Candy as 500 pounds.

**Japan.**

*Length.* The Sun = 1·20 inches; 10 Sun = 1 Shiaku = 1 foot nearly; 10 Shiaku = 1 Jô = 9 feet $11\frac{1}{4}$ inches; 60 Ken = 1 Chô = 119·4 yards; 36 Chô = 1 Ri = 2·442 miles. Cloth is measured by the Shiaku of 15 inches, divided decimally.

*Surface.* 30 Tsubo = 1 Se = 118·615 square yards; 100 Se = 1 Chō = 2·451 acres.

*Capacity.* 10 Gō = 1 Shō = ·3973 gallon; 10 Shō = 1 To = 3·970 gallons; 10 To = 1 Koku = 39·703 gallons.

*Weight.* 10 Fun = 1 Momme = 57·97 grains; 100 Momme = 1 Hiyaku-me = ·828 pound; 1000 Momme = 1 Kwam-me = 8·282 pounds; 160 Momme = 1 Kiu = 1⅓ pounds; 100 Kiu = 1 Hiyak-Kin = 132½ pounds.

### Java. (*See* Dutch East Indies.)

### Persia.

The unit of length is the Zer, of various lengths; the most common length is 40·95 inches. 16 Gerehs = 1 Zer. A Farsakh varies from 3·87 miles to 4½ miles in length.

*Surface.* The measure of surface is the Jerib = from 1000 to 1066 square Zer of 40·95 inches = from 1294 to 1379 square yards.

*Capacity.* (Dry Goods.) 1 Sextario = ·07236 gallon; 1 Artata = 1·809 bushels. Liquids are sold by weight.

*Weight.* The unit of weight is the Miskâl = 71 grains; 100 Miskâls = 1 Rotel = 1·014 pounds. 640 Miskâls = 1 Batman (of Tabreez) = 6·49 pounds; 100 Batman (of Tabreez) = 1 Karwâr = 649·142 pounds.

The Batman or Mau is the weight by which most articles are sold. It has very various values in different districts. Corn, straw, coal, &c., are sold by the Karwâr.

### Siam.

1 Niu = ·9875 inch; 1 Sen = 131 feet 8 inches; 1 Yot = 9 miles, 1715 yards, 1 foot, 8 inches. 1 Chang = 2⅔ pounds; 50 Chang = 133⅓ pounds.

### Straits Settlements.

The unit measure of length is the yard; land is measured by the acre.

The Chupak or quart, of 4 paus = 8 imperial gills; 4 quarts = 1 gantang or gallon = 32 gills.

16 Tahil = 1 Kati = 1⅓ pound; 100 Kati = 1 Picul = 133⅓ pounds; 40 Picul = 1 Koyan = 5333⅓ pounds.

## AUSTRALASIA.

In Fiji, New South Wales, New Zealand, Queensland, South Australia, Tasmania, Victoria, Western Australia, the legal

weights and measures are those of the United Kingdom. But the old British measures of capacity are still in use.

In land measurement, a "section" is an area equal to 80 acres.

## AFRICA.

### Algeria.

The French metrical system only is in use.

### Arabia.

The Egyptian weights and measures are used in Arabia.

### Cape Colony.

The British system of weights and measures is in use; excepting for land measure, for which the unit is the old Amsterdam Morgen, equal to 2·11654 acres; but it is usually reckoned as 2 acres.

1 Cape foot is equal to 1·033 British foot.

### Egypt.

The French metric system was legally established in Egypt in 1876.

*Length.* In the old system in general use the Pik is the unit of length. The Pik or cubit of the Nile = 20·65 inches: the indigenous Pik = 22·37 inches; the Pik of merchandise = 25·51 inches: the Pik of construction = 29·53 inches; 4·73 Piks of construction = 1 Kassaba, in surveying = 11·65 feet.

*Surface.* 1 square Pik = 6·055 square feet; 22·41 square Piks = 1 square Kassaba = 15·07 square yards; 333·33 square Kassaba = 1 Feddan = ·9342 acre.

*Capacity.* 1 Kelah = 3·367 gallons; 2 Kelahs = 1 Webek = 6·734 gallons; 6 Webeks = 1 Ardeb = 40·404 gallons = 6·48 cubic feet. The Guirbah of water is $\frac{1}{15}$ cubic metre = 2·354 cubic feet.

*Weight.* 16 Kerats = 1 Dirhem = 1·792 drachms; 12 Okiehs or 144 Dirhems = 1 Rottol = ·9821 pound; 100 Rottols = 1 Kantar = 98·207 pounds. 1 Oke = 2·728 pounds.

### Liberia.

The weights and measures of Liberia are mostly British.

### Mauritius.

The metric system, decreed by the Government of India in 1871, came into force in Mauritius in 1878.

### Morocco.

*Length.* 8 Tomins = 1 Drah = 22·482 inches.

*Capacity.* 4 Muhds = 1 Saâ = 12·3254 gallons.

*Weight.* 20 Uckieh = 1 Rotal or Artal = 1·12 pounds; 100 Rotals = 1 Kintar = 112 pounds; for imported articles. There is also the Kintar of 168 pounds (100 Rotals) for internal produce.

Oil is sold by the Kula; the Tangier Kula weighs 28 Rotals = 47 pounds English = 5·29 gallons.

### South African Republic.

The weights and measures are the same as those of Cape Colony.

### Tunis.

*Length.* The Dhraâ or Pike is the unit of length. The Arabian Dhraâ, for cotton goods, is 19·224 inches long; the Turkish Dhraâ, for lace and silk; the Dhraâ Endaseh for cloth, 26·4888 inches. The Mil Sahári = ·9149 mile.

*Capacity.* The Kaffis = 16 Huebas, each of 12 Sahs = 16 bushels.

*Weight.* 100 Rottolos = 1 Cantar = 109·15 pounds.

## AMERICA.

### Argentine Republic.

The French metric system was, in 1887, legally and compulsorily established. The old weights and measures comprised the Quintal of 101·40 pounds; the Arroba, 25·35 pounds; the Fanega, 1½ bushels.

### Bolivia.

The Vara = ·927 yard; the square Vara = ·859 square yard.

The gallon = ·74 imperial gallon; the Arroba, of 25 pounds, = 25·36 pounds avoirdupois; the Arroba for wines and spirits = 6·70 imperial gallons.

The ounce = 1·014 ounce avoirdupois; 16 ounces = 1 Libra = 1·014 pound; 100 Libras = 1 Quintal = 101·44 pounds.

### Brazil.

The French metric system is legally established. The old weights and measures are still partly in use.

*Length.* The Pollegada = 1·0936 inches; the Pé = 13·1236 inches, or ⅓ metre; the Vara = 1·215 yards; the Milha = 1·2965 miles; 3 Milhas = 1 Legoa = 3·8896 miles; 5 Varas are reckoned equal to 6 yards.

*Surface.* 64 square Polegadas = 1 square Palmo = ·5315 square foot; 25 square Palmos = 1 square Vara; 4 square Varas = 1 square Braça = 5·9063 square yards; 4840 square Varas = 1 Geira = 1·4766 acres.

*Weight.* The Arratel = 1·0119 pounds; 32 Arratels = 1 Arroba = 32·38 pounds; 4 Arrobas = 1 Quintal = 129·518 pounds; 13½ Quintals = 1 Tonelada = 15·6116 hundredwts. Ship's freight is reckoned by the English ton taken as equal to 70 Arrobas.

## Canada.

The legal weights and measures are the Imperial yard, the Imperial pound avoirdupois, the Imperial gallon, and the Imperial bushel. The Imperial system is practised, with the exception that the hundredweight = 100 pounds, and the ton = 2000 pounds. The French metric system is permissive, concurrently with the Standard System.

For sale and delivery of the undermentioned articles, the bushel is to be determined by weighing, unless a bushel by measure be specially agreed upon. The weights equivalent to a bushel are added:—

| | lbs. | | lbs. |
|---|---|---|---|
| Wheat | 60 | Potatoes, Turnips, Carrots | 60 |
| Indian corn | 56 | Parsnips, Beets, Onions | 60 |
| Rye | 56 | Bituminous coal | 70 |
| Peas | 60 | Clover seed | 60 |
| Barley | 48 | Timothy | 48 |
| Malt | 36 | Buck wheat | 48 |
| Oats | 34 | | |
| Beans | 60 | | |
| Flax seed | 50 | | |
| Hemp | 44 | | |
| Blue grass seed | 14 | | |
| Castor beans | 40 | | |

## Chili.

The French metric system has been legally established in Chili; but the ancient weights and measures are still in use. These are the same as those of Bolivia.

## Colombia.

The French metric system is legally established in Colombia. In Custom House business, the kilogramme is the standard of weight. The old weights and measures continue in use in ordinary commerce. The Arroba, of 25 Spanish pounds or 12½ kilogrammes; the Quintal, of 100 Spanish pounds, or 50 kilogrammes; and the Carga, of 250 Spanish pounds, or 125 kilogrammes, are generally used. The libra, or pound

is equal to 1·102 pounds avoirdupois. The yard is the usual measure of length. The Colombian Vara, 80 centimetres, is also used. In liquid measure, the French litre is the legal standard.

**Costa Rica.**

The French metric system is in use, and its legal establishment is contemplated. The old weights and measures of Spain are in general use.

**Cuba.**

The old weights and measures of Spain are in general use. In engineering and carpentry, English and French measures also are in use. The French metric system is legalised, and is used in the Customs departments.

**Ecuador.**

The French metric system is the legal standard of this republic.

**Guatemala.**

The old weights and measures of Spain are in general use in Guatemala.

**Haiti.**

The French metric weights and measures are in use in Haiti.

**Honduras.**

The old weights and measures of Spain are in general use in Honduras.

**British Honduras.**

The British weights and measures are in use in British Honduras.

**Mexico.**

The weights and measures of the French metric system are legally established in Mexico. But the old Spanish measures are still in use.

**Nicaragua.**

The system of weights and measures in Nicaragua is that of the old weights and measures of Spain.

**Paraguay.**

The old weights and measures of Spain are in general use in Paraguay.

## Peru.

The old weights and measures are the same as those of Bolivia and Chili. The French metric system was established in 1860, but is not yet in common use, except for the Customs tariff.

## Salvador.

The weights and measures in common use in Salvador are the same as in the old Spanish system. The French metric system was introduced in 1885.

## St. Domingo.

The old Spanish weights and measures are in general use. The French metric system also is in use.

## United States of America.

The British Imperial system of weights and measures is employed in the United States, with the exception of the measures of capacity for dry goods and for liquids, which are the same as the old English measures. The standard U.S. gallon is the same as the old English wine gallon, or 231 cubic inches, capable of holding 8·33888 pounds of pure water of maximum density, at 39·1° F.; or $8\frac{1}{3}$ pounds at 62° F. The U.S. gallon is thus $83\frac{1}{3}$ per cent. or $\frac{5}{6}$ths of the Imperial standard gallon.

The chain for land measurement is 100 feet long, and each foot is divided into tenths.

In City measurements the inch is the unit, divided into tenths.

In mechanical measurements, the inch is the unit, divided into 100 parts.

1 cord of wood is (4 feet × 4 feet × 8 feet) = 128 cubic feet.

In addition to the legalised scale of weights, the same as that of Great Britain and Ireland, there are the Quintal or Centner of 100 pounds; and the New York ton of 2,000 pounds, which is also used in the other States of the Union. These, the Centner and the New York ton, have practically superseded the British hundredweight and ton.

The French metric system of weights and measures has been legalised concurrently with the existing system.

### Table 69.—American Standard Wire-Gauge.
(Brown and Sharpe's.)
For Sheets and Wire.

| Mark. | Size. | Mark. | Size. | Mark. | Size. | Mark. | Size. |
|---|---|---|---|---|---|---|---|
| | Inch. | | Inch. | | Inch. | | Inch. |
| 4/0 | .4600 | 8 | ·1285 | 19 | ·0359 | 30 | ·01003 |
| 3/0 | ·4096 | 9 | ·1144 | 20 | ·0320 | 31 | ·00893 |
| 2/0 | ·3648 | 10 | ·1019 | 21 | ·0285 | 32 | ·00795 |
| 0 | ·3249 | 11 | ·0907 | 22 | ·0253 | 33 | ·00708 |
| 1 | ·2893 | 12 | ·0808 | 23 | ·0226 | 34 | ·00603 |
| 2 | ·2576 | 13 | ·0720 | 24 | ·0201 | 35 | ·00561 |
| 3 | ·2294 | 14 | ·0641 | 25 | ·0179 | 36 | ·00500 |
| 4 | ·2043 | 15 | ·0571 | 26 | ·0159 | 37 | ·00445 |
| 5 | ·1819 | 16 | ·0508 | 27 | ·0142 | 38 | ·00397 |
| 6 | ·1620 | 17 | ·0453 | 28 | ·0126 | 39 | ·00353 |
| 7 | ·1443 | 18 | ·0403 | 29 | ·0113 | 40 | ·00314 |

### Table 70.—Liquid Measure (American).

| | | Imperial Gallons. |
|---|---|---|
| 4 gills | 1 pint | |
| 2 pints | 1 quart | |
| 4 quarts (231 cubic inches) | 1 gallon | ·8333 |
| 31½ gallons | 1 barrel | 26·250 |
| 63 gallons | 1 hogshead | 52·50 |
| 2 hogsheads | 1 pipe, or butt | 105·00 |
| 2 pipes | 1 tun | 210·00 |

### Table 71.—Dry Measure (American).

| | | |
|---|---|---|
| 2 pints | 1 quart | |
| 4 quarts (268·8025 cubic inches) | 1 gallon | ·96945 Imperial gallon. |
| 2 gallons | 1 peck | 1·9388 do. peck |
| 4 pecks | 1 struck bushel | ·96945 do. bushel |

## Uruguay.

The French metrical system has been officially adopted; but it is not in general use. The old weights and measures are the same as those of the Argentine Republic. The weights and measures of Brazil are in general use.

## Venezuela.

The French metrical system has been legally established. The system in general use is the same as that of Colombia.

## West Indies.

The weights and measures are the same as those of the United Kingdom.

# MONEY.

## Great Britain and Ireland.

| | | Weight. Grains. |
|---|---|---|
| 4 farthings / 2 halfpence | 1 penny | 145·833 bronze. |
| 3 pence | 1 threepenny piece | 21·818 silver. |
| 6 pence | 1 sixpence | 43·636 ,, |
| 12 pence | 1 shilling | 87·273 ,, |
| 2 shillings | 1 florin | 174·545 ,, |
| $2\frac{1}{2}$ shillings | 1 half-crown | 218·182 ,, |
| 10 shillings | 1 half-sovereign | 61·6372 gold. |
| 20 shillings | 1 sovereign, or pound sterling | 123·2745 ,, |

### *Approximate Diameters and Weights.*

| | Diameter. | | Weight. | |
|---|---|---|---|---|
| 1 farthing | ·80 inch | | $\frac{1}{10}$ ounce. | |
| 1 halfpenny | 1·0 ,, | | $\frac{1}{5}$ ,, | |
| 1 penny | 1·2 ,, | | $\frac{1}{3}$ ,, | |
| 1 threepenny piece | $\frac{5}{8}$ ,, | | $\frac{1}{20}$ ,, | |
| 1 sixpence | $\frac{3}{4}$ ,, | | $\frac{1}{10}$ ,, | |
| 1 shilling | $\frac{29}{32}$ ,, | or ·90 inch | $\frac{1}{5}$ ,, | |
| 1 florin | $1\frac{5}{32}$ ,, | or 1·16 ,, | $\frac{2}{5}$ ,, | |
| 1 half-crown | $1\frac{1}{4}$ ,, | | $\frac{1}{2}$ ,, | |
| 1 half-sovereign | $\frac{3}{4}$ ,, | | $\frac{1}{7}$ ,, | fully. |
| 1 sovereign | $\frac{27}{32}$ ,, | or ·84 inch | $\frac{2}{7}$ ,, | fully. |

### *Composition.*

Bronze :—Copper, tin, and zinc.
Silver :—Fine silver, $92\frac{1}{2}$ per cent. ; alloy, $7\frac{1}{2}$ per cent.
Gold :—Fine gold, $91\frac{2}{3}$ per cent. ; alloy, $8\frac{1}{3}$ per cent.

### *Intrinsic Value.*

480 pence equal to £1 sterling.
22 shillings equal to £1 sterling.
Mint price of Standard Gold, £3 17*s.* $10\frac{1}{2}$*d.* per ounce.

## France.

| *Bronze.* | | Weight. | Diameter. | Equivalent Value. Penny. |
|---|---|---|---|---|
| 1 centime | $\frac{1}{100}$ franc | 1 gramme | 15 millimetres | ·10 |
| 2 centimes | $\frac{1}{50}$ ,, | 2 ,, | 20 ,, | ·20 |
| 5 centimes (*sou*) | $\frac{1}{20}$ ,, | 5 ,, | 25 ,, | ·50 |
| 10 centimes (*gros sou*) | $\frac{1}{10}$ ,, | 10 ,, | 30 ,, | 1·00 |

| *Silver.* | | Weight. | Diameter. | Equivalent Value. Pence. |
|---|---|---|---|---|
| 20 centimes | $\frac{1}{5}$ franc | 1 gramme | 16 millimetres | 2 |
| 50 centimes | $\frac{1}{2}$ ,, | 2·5 ,, | 18 ,, | $4\frac{3}{4}$ |
| 100 centimes | 1 ,, | 5 ,, | 23 ,, | $9\frac{1}{2}$ more exactly 9·524 |
| 2 francs . | 2 ,, | 10 ,, | 27 ,, | 1*s.* 7*d.* |
| 5 francs . | 5 ,, | 25 ,, | 37 ,, | 3*s.* $11\frac{5}{8}$*d.* |

| *Gold.* | Weight | Diameter | £ | *s.* | *d.* |
|---|---|---|---|---|---|
| 5 francs . | 1·61290 grammes | 17 millimetres | | 3 | $11\frac{5}{8}$ |
| 10 francs . | 3·22580 ,, | 19 ,, | | 7 | $11\frac{1}{4}$ |
| 20 francs (napoleon) | 6·45161 ,, =99·56 grains | 21 ,, | | 15 | $10\frac{1}{2}$ |
| 50 francs . | 16·12903 grammes | 28 ,, | 1 | 19 | $8\frac{1}{5}$ |
| 100 francs . | 32·25806 ,, | 35 ,, | 3 | 19 | $4\frac{4}{10}$ |

The above English values of French coins are calculated at the rate of 25 francs 20 centimes to £1 sterling. The standard fineness of the gold pieces is 90 per cent., with 10 per cent. of copper.

A Monetary Convention exists between France, Belgium, Italy, Switzerland, and Spain, adopting the gold and silver coins above noted.

### Germany.

The mark, of 100 pfennigs, is a silver coin of the value of $11\frac{3}{4}$ pence. The 10-mark gold piece is of the value of 9*s.* $9\frac{1}{2}$*d.* English money. The 20-mark gold piece is equivalent to 19*s.* 7*d.*; it weighs 122·92 grains. One thaler is nearly equal to 3 marks; it is equal to 3 shillings.

### Other Countries in Europe.

*Belgium.*—The monetary system is the same as that of France.

*Denmark.*—There is a decimal system of currency. 1 krone =100 öre. 18 krones=£1.

*Greece.*—The drachma=1 franc; and 100 lepta=1 drachma.

*Italy.*—The monetary system is the same as that of France. The lira, of 100 centesimi, =1 franc.

*The Netherlands.*—The guilder or florin, of 100 cents, = 1*s.* 8*d.* English; or 12 guilders=£1.

*Portugal.*—The milreis, or 1,000 reis, = 4*s.* $5\frac{1}{3}$*d.*; about $4\frac{1}{2}$ milreis=£1; $18\frac{3}{4}$ reis=1 penny. One corda (gold coin) = 10,000 reis=£2 4*s.* $5\frac{1}{2}$*d.*; and weighs 17·735 grammes.

*Roumania.*—The French decimal monetary system is practised, of which the unit is the leï=1 franc.

*Russia.*—The silver rouble = 100 kopecks, is the legal unit of money = 3*s.* 2·054*d.* English. There are three gold coins; the three-rouble, five-rouble, and ten-rouble pieces. The marc of Finland = 1 franc.

*Servia.*—The French monetary system is adopted. The dinar = 1 franc. The gold milan = 20 francs.

*Spain.*—The peseta, of 100 centimos, = 1 franc. It is equal to 4 reals, of which there are about 100 to the £1. The 25-peseta piece is 19*s.* 9½*d.* English value.

*Sweden, Norway.*—The Swedish krona, of 100 ôre, = 1*s.* 1⅓*d.*; or 18 to £1. Norway.—The krone is of the same value as the Swedish krona.

*Switzerland.*—The French monetary system is legalised. The franc = 10 batzen = 100 rappen.

*Turkey.*—The lira or gold medjidieh, of 100 piastres, = 18*s.* ·064*d.* The piastre = 2·16*d.*

## Malta.

1 scudo of 12 tari = 1*s.* 8*d.* British money is in general circulation. The English sovereign is equal to 12 scudi; the shilling is equal to 7 tari 4 grani (20 grani = 1 taro).

## Cyprus.

1 piastra, of 40 para, = 1·4*d.* English. Turkish, English, and French moneys also are in circulation.

## Asia.

*Ceylon.*—The rupee of British India, with cents. The exchange value in 1887 was 1*s.* 6*d.*

*China.*—The haikwan tael = 10 mace = 100 candereens = 1,000 cash. Rate of exchange in 1887, 5*s.* 0⅛*d.*

*Dutch East Indies.—Java.*—The guilder, or florin = 100 centen = 1*s.* 8*d.*

*Hong Kong.*—The Mexican dollar = 100 cents; average rate of exchange, 3*s.* 2*d.* The Chinese tael = 4*s.* 5*d.*

*India.*—The pie = ½ farthing; 3 pie = 1 pice = 1½ farthing; 4 pice = 1 anna = 1½*d.*; 16 annas = 16 rupee = 2*s.* 15 rupees = 1 gold mohur = 30*s.* 100,000 rupees is a lac of rupees; 10 millions are a crore of rupees.

*Japan.*—The yen, or dollar, of 100 sens; nominal value, 4*s.*; real value (1887), 3*s.* 4*d.*

*Persia.*—The krân is 7⅛*d.* = 20 shâhîs; 1 shahi = ·3582*d.*

*Siam.*—1 tical or bat = 64 atts; rate of exchange, 2*s.* 1*d.*

*Straits Settlements.*—The legal tenders are, the dollar issued from Her Majesty's Mint at Hong Kong, the silver dollar of

Spain, Mexico, Peru, Bolivia, the American trade dollar, and the Japanese dollar, or yen.

*Australasia.*—The moneys are the same as those of the United Kingdom.

## Africa.

*Algeria.*—The French monetary system is practised.

*Cape Colony.*—The English monetary system is practised.

*Egypt.*—1 piastre (tariff) of 10 dimes or 40 paras = 2·461 pence; 97½ piastres = £1 sterling; 100 piastres = £1 Egyptian = £1 0*s*. 6*d*. 1 piastre (tariff) = 2 piastres (current).

*Liberia.*—Chiefly British money current.

*Madagascar.*—The only legalised coin is the silver five-franc piece. The Italian five-lire piece is accepted.

*Mauritius.*—The Indian rupee is the standard coin.

| | | | |
|---|---|---|---|
| *Morocco.*—6 floos | = 1 blankeel or muzoona | = ·09 | penny. |
| 4 blankeels | = 1 ounce, or okia | = ·38 | ,, |
| 10 ounces | = 1 mitkal | = 3·08 | ,, |

Spanish and French money are current in Morocco.

*Tunis.*—The piastre, of 16 karubs; average value, 6*d*. Spanish and French money are current in Tunis.

*Zanzibar.*—The Indian rupee is the coin universally current; though there is a special coinage issued under the authority of the Sultan, of which the dollar is the unit, of equal value with the American coins.

## America.

*Argentine Republic.*—The silver dollar of 100 centesimos; average rate of exchange, 4*s*.

*Bolivia.*—The boliviano, or dollar of 100 centesimos, struck on the basis of the five-franc piece. Present value (1887), 3*s*. 4*d*.

*Brazil.*—The milreis of 1,000 reis. Par value, 2*s*. 3*d*.

*Canada.*—The dollar, of 100 cents; rate of exchange, 4*s*. The value of the English sovereign is by law equal to 4 dollars and 86⅔ cents.

*Chili.*—The silver peso, of 100 centavos; nominally 1 dollar, but actually coined on the basis of the five-franc piece; value, 3*s*. 4*d*.

*Colombia.*—The peso or dollar, of 10 reals; actual value, 3*s*. 4*d*.; nominally, 4*s*.

*Costa Rica.*—The dollar of 100 centavos; nominal value, 4*s*.; present value, 3*s*. 6*d*.

*Equador.*—The monetary unit is the sueré, equal to a five-franc piece. Average rate of exchange, 36⅓ pence.

*Guatemala.*—The dollar, or piaster, of 100 centavas; approximate value, 4*s.*

*Haiti.*—The dollar, or piastre; nominal value, 4*s.*; real value, 3*s.* 4*d.*

*Honduras.*—The dollar of 100 cents; nominal value, 4*s.*; real value, 3*s.* 4*d.*

*Mexico.*—The silver peso of 100 cents; nominal value, 4*s.*; real value, 3*s.* 1½*d.*

*Nicaragua.*—The same as for Honduras.

*Paraguay.*—The peso, or dollar = 100 centavos; nominal value, 4*s.*; real value, 3*s.*

*Peru.*—The sole = 100 centesimos; nominal value, 4*s.*; real value, 3*s.* 4*d.*

*Salvador.*—The peso, or piastre, of 8 reals; approximate value, 4*s.* 3½*d.* The dollar of 100 centavos, 4*s.*

*San Domingo.*—The same as for Spain.

*United States.*—The dollar of 100 cents. Par value, 49·32*d.*: or £1 = 4·866 dollars.

*Uruguay.*—The peso, or dollar, of 100 centevas; approximate value, 4*s.* 3*d.*; or £1 = 4·70 dollars.

*Venezuela.*—The venezolano of 100 centavas; approximate value, 3*s.* 4*d.* The bolivar = 1 franc.

## SPECIFIC GRAVITY, WEIGHT, AND VOLUME.

### Density of Alloys and Amalgams.

Messrs. F. Crace-Calvert and Richard Johnson investigated the conductibility of heat, tenacity, hardness, and expansion of alloys and amalgams formed with pure metals, according to the law of equivalents, and that of multiple preparations, the results of which are recorded in Table 72. It was discovered that all alloys of copper, in course of formation, make a contraction of volume; whilst all the amalgams dilate and have less than the mean density calculated in terms of the densities and proportions of the elements. Also that the maximum contraction or dilation of an alloy or an amalgam takes place generally when an equivalent of each metal is taken, except in the case of tin and zinc. These general results are attributable, no doubt, to the fact of all the alloys, except these last-named, being combinations, not mixtures. Some alloys have exceptionally great contraction or dilation. Thus, the alloy of 3 equivalents of copper to 1 of tin, has 8·954 density; calculated as a mixture, its density would only be 8·208. The amalgam of one equivalent of tin

with one of mercury dilates by one-tenth of the elementary volumes.

TABLE 72.—METALS: SPECIFIC GRAVITY, WEIGHT, AND VOLUME.

| METALS. | Specific Gravity. | Weight of One Cubic Foot. | Weight of One Cubic Inch. | Cubic Feet per Ton. |
|---|---|---|---|---|
| | Water =1. | Lbs. | Ozs. | Cubic Feet. |
| Aluminium, wrought | 2·67 | 167 | 1·55 | 13·44 |
| „ cast | 2·56 | 160 | 1·48 | 14·02 |
| Antimony | 6·71 | 418 | 3·87 | 5·35 |
| Arsenic | 5·80 | 361·5 | 3·35 | 6·19 |
| Bismuth | 9·90 | 617 | 6·03 | 3·63 |
| Brass, cast :— | 8·10 | 505 | 4·71 | 4·43 |
| 75 copper, 25 zinc, sheet | 8·45 | 527 | 4·87 | 4·25 |
| 66 „ 34 „ yellow | 8·30 | 518 | 4·80 | 4·32 |
| 60 „ 40 „ Muntz's metal | 8·20 | 511 | 4·73 | 4·38 |
| Brass wire | 8·55 | 533 | 4·93 | 4·20 |
| Bronze :— | | | | |
| 84 copper, 16 tin, gun metal | 8·56 | 534 | 4·93 | 4·19 |
| 83 „ 17 „ „ | 8·46 | 528 | 4·89 | 4·24 |
| 81 „ 19 „ „ | 8·46 | 528 | 4·89 | 4·24 |
| 79 „ 21 „ mill bearings | 8·73 | 544 | 5·04 | 4·11 |
| 35 „ 65 „ small bells | 8·06 | 503 | 4·66 | 4·45 |
| 21 „ 79 „ „ | 7·39 | 461 | 4·27 | 4·86 |
| 15 „ 85 „ speculum metal | 7·45 | 465 | 4·31 | 4·82 |
| Calcium | 1·58 | 98·5 | 0·91 | 22·72 |
| Cobalt | 8·50 | 530 | 4·91 | 4·22 |
| Chromium | 6·00 | 374 | 3·46 | 5·98 |
| Copper, sheet | 8·81 | 549 | 5·08 | 4·08 |
| „ hammered | 8·92 | 556 | 5·19 | 4·02 |
| „ wire | 8·88 | 554 | 5·13 | 4·04 |
| Gold | 19·24 | 1200 | 11·11 | 1·87 |
| Iron, cast :— | | | | |
| white | 7·50 | 468 | 4·33 | 4·79 |
| grey | 7·20 | 449 | 4·16 | 4·99 |
| hot blast | 6·97 | 435 | 4·03 | 5·15 |
| „ 14th melting | 7·53 | 470 | 4·35 | 4·77 |
| mean, for ordinary calculations | 7·22 | 450 | 4·17 | 5·00 |

TABLE 72.—METALS: SPECIFIC GRAVITY, WEIGHT, AND VOLUME (*continued.*)

| Metals. | Specific Gravity. | Weight of One Cubic Foot. | Weight of One Cubic Inch. | Cubic Feet per Ton. |
|---|---|---|---|---|
| | Water = 1. | Pounds. | Ozs. | Cubic Ft. |
| Iron, wrought:— | | | | |
| common bar, rails | 7·55 | 471 | 4·36 | 4·76 |
| puddled slab | 7·53 to 7·60 | 469·5 to 474 | 4·35 to 4·39 | 4·77 to 4·72 |
| various (Kirkaldy), mean | 7·65 | 477 | 4·42 | 4·69 |
| Yorkshire bar | 7·76 | 484 | 4·48 | 4·63 |
| Low Moor plates, thick | 7·81 | 487 | 4·51 | 4·60 |
| pure iron, by electro-deposit | 8·14 | 508 | 4·70 | 4·41 |
| mean, for ordinary calculations | 7·70 | 480 | 4·44 | 4·66 |
| Lead, milled sheet | 11·42 | 712 | 6·59 | 3·14 |
| „ wire | 11·28 | 704 | 6·52 | 3·18 |
| Lithium | ·59 | 37 | ·34 | 6·08 |
| Magnesium | 1·74 | 108·5 | 10·00 | 20·63 |
| Manganese | 8·00 | 499 | 4·51 | 4·49 |
| Mercury | 13·60 | 849 | 7·86 | 2·64 |
| Nickel, hammered | 8·67 | 541 | 5·09 | 4·14 |
| „ cast | 8·28 | 516 | 4·78 | 4·34 |
| Platinum | 21·52 | 1342 | 12·42 | 1·67 |
| Potassium | ·86 | 53·6 | ·41 | 41·65 |
| Silver | 10·50 | 655 | 6·06 | 3·42 |
| Sodium | ·97 | 60·5 | ·56 | 37·01 |
| Steel:— | | | | |
| blistered | 7·82 | 488 | 4·52 | 4·59 |
| crucible | 7·84 | 489 | 4·53 | 4·58 |
| cast | 7·85 | 489·3 | 4·53 | 4·57 |
| Bessemer | 7·85 | 489·6 | 4·53 | 4·57 |
| for ordinary calculations | 7·86 | 490 | 4·54 | 4·57 |
| Tin | 7·41 | 462 | 4·29 | 4·84 |
| Zinc, sheet | 7·20 | 449 | 4·16 | 4·99 |
| „ cast | 6·86 | 428 | 4·02 | 5·23 |

## Table 73.—Density of Alloys and Amalgams.

(F. Crace-Calvert and R. Johnson.)

### I. ALLOYS OF GREATER THAN CALCULATED MEAN DENSITY: WITH CONTRACTION.

| Alloy. | Proportions per cent. by Weight. | Density obtained. | Density calculated. | Difference. |
|---|---|---|---|---|
| 1. *Copper and Tin* (bronze) | | | | |
| Cu $Sn^5$ | C 9·73, T 90·27 | 7·517 | 7·431 | ·086 |
| Cu $Sn^4$ | C 11·86, T 88·14 | 7·558 | 7·462 | ·096 |
| Cu $Sn^3$ | C 15·21, T 84·79 | 7·606 | 7·514 | ·092 |
| Cu $Sn^2$ | C 21·21, T 78·79 | 7·738 | 7·580 | ·158 |
| Cu Sn | C 34·98, T 65·02 | 7·992 | 7·805 | ·187 |
| Sn $Cu^2$ | T 51·83, C 48·17 | 8·533 | 8·059 | ·474 |
| Sn $Cu^3$ | T 38·21, C 61·79 | 8·954 | 8·208 | ·746 |
| Sn $Cu^4$ | T 31·73, C 68·27 | 8·948 | 8·306 | ·642 |
| Sn $Cu^5$ | T 27·10, C 72·90 | 8·965 | 8·374 | ·591 |
| Sn $Cu^{10}$ | T 15·68, C 84·32 | 8·832 | 8·545 | ·287 |
| Sn $Cu^{15}$ | T 11·03, C 88·97 | 8·825 | 8·615 | ·210 |
| Sn $Cu^{20}$ | T 8·51, C 91·49 | 8·793 | 8·634 | ·159 |
| Sn $Cu^{25}$ | T 6·83, C 93·17 | 8·820 | 8·677 | ·143 |
| 2. *Copper and Zinc* (brass) | | | | |
| Zn $Cu^5$ | C 82·95, Z 17·05 | 8·673 | 8·453 | ·220 |
| Zn $Cu^4$ | C 79·56, Z 20·44 | 8·650 | 8·387 | ·263 |
| Zn $Cu^3$ | C 74·48, Z 25·52 | 8·576 | 8·290 | ·286 |

TABLE 73.—DENSITY OF ALLOYS AND AMALGAMS (*continued*).

| ALLOY. | Proportions per cent. by Weight. | Density obtained. | Density calculated. | Difference. |
|---|---|---|---|---|
| 2. *Copper and Zinc* (brass) (*continued.*) | | | | |
| Zn $Cu^2$ . . . . | C 66·06<br>Z 33·94 | 8·488 | 8·129 | ·359 |
| Zn Cu . . . . . | C 49·32<br>Z 50·58 | 7·808 | 8·319 | ·511 |
| Cu $Zn^2$ . . . . | C 32·74<br>Z 67·26 | 7·859 | 7·489 | ·370 |
| Cu $Zn^3$ . . . . . | C 24·64<br>Z 75·36 | 7·736 | 7·334 | ·401 |
| Cu $Zn^4$ . . . . | C 19·57<br>Z 80·43 | 7·445 | 7·237 | ·208 |
| Cu $Zn^5$ . . . . . | C 16·30<br>Z 83·70 | 7·442 | 7·174 | ·208 |
| 3. *Copper and Bismuth.* | | | | |
| Cu Bi . . . . . | | 9·634 | 9·566 | ·068 |
| 4. *Copper and Antimony.* | | | | |
| Cu Sb . . . . . | | 7·990 | 7·386 | ·604 |
| 5. *Tin and Zinc.* | | | | |
| Zn $Sn^2$ . . . . | Z 21·65<br>T 78·35 | 7·274 | 7·193 | ·081 |
| Zn Sn . . . . . | Z 35·60<br>T 64·40 | 7·262 | 7·134 | ·128 |
| Sn $Zn^2$ . . . . | T 47·49<br>Z 52·51 | 7·188 | 7·060 | ·128 |
| Sn $Zn^3$ . . . . . | T 37·57<br>Z 62·43 | 7·180 | 7·021 | ·159 |
| Sn $Zn^4$ . . . . | T 31·14<br>Z 68·86 | 7·155 | 6·993 | ·162 |
| Sn $Zn^5$ . . . . . | T 26·57<br>Z 73·43 | 7·140 | 6·974 | ·161 |
| Sn $Zn^{10}$ . . . . | T 15·32<br>Z 84·68 | 7·135 | 6·927 | ·208 |

TABLE 73.—DENSITY OF ALLOYS AND AMALGAMS (*continued*).

II. ALLOYS AND AMALGAMS OF LESS THAN CALCULATED MEAN DENSITY: WITH DILATATION.

| ALLOY. | Proportions per cent. by Weight. | Density obtained. | Density calculated. | Difference. |
|---|---|---|---|---|
| 6. *Mercury and Tin.* | | | | |
| Hg Sn . . . . . | M 62·97<br>T 37·03 | 10·255 | 11·259 | 1·004 |
| $Hg\ Sn^2$ . . . . | M 45·88<br>T 54·12 | 9·314 | 10·180 | ·866 |
| $Hg\ Sn^3$ . . . . . | M 36·18<br>T 63·82 | 8·805 | 9·568 | ·763 |
| $Hg\ Sn^4$ . . . . | M 29·84<br>T 70·16 | 8·510 | 9·168 | ·658 |
| $Hg\ Sn^5$ . . . . . | M 25·38<br>T 74·62 | 8·312 | 8·885 | ·573 |
| $Hg\ Sn^6$ . . . . | M 22·08<br>T 77·92 | 8·151 | 8·678 | ·527 |
| 7. *Mercury and Bismuth.* | | | | |
| Hg Bi . . . . . | M 48·44<br>B 51·56 | 11·208 | 11·638 | ·430 |
| $Hg\ Bi^2$ . . . . | M 31·82<br>B 68·18 | 10·693 | 11·007 | ·314 |
| $Hg\ Bi^3$ . . . . . | M 23·86<br>B 76·14 | 10·474 | 10·704 | ·230 |
| $Hg\ Bi^4$ . . . . | M 19·03<br>B 80·97 | 10·350 | 10·522 | ·172 |
| $Hg\ Bi^5$ . . . . . | M 15·82<br>B 84·18 | 10·240 | 10·410 | ·170 |
| 8. *Mercury and Zinc* . | | 11·304 | 11·944 | ·640 |
| 9. *Antimony and Bismuth* | | | | |
| $Bi\ Sb^5$ . . . . . | B 24·81<br>A 75·19 | 7·271 | 7·470 | ·201 |
| $Bi\ Sb^4$ . . . . | B 29·20<br>A 70·80 | 7·370 | 7·606 | ·235 |
| $Bi\ Sb^3$ . . . . . | B 35·48<br>A 64·52 | 7·561 | 7·801 | ·240 |
| $Bi\ Sb^2$ . . . | B 45·21<br>A 54·79 | 7·829 | 8·102 | ·273 |
| Bi Sb . . . . . | B 62·26<br>A 37·94 | 8·364 | 8·630 | ·268 |

## Table 73.—Density of Alloys and Amalgams (*continued*).

| Alloy. | Proportions per cent. by Weight. | Density obtained. | Density calculated. | Difference. |
|---|---|---|---|---|
| 9. *Antimony and Bismuth (continued).* | | | | |
| Sb $Bi^2$ | A 23·26, B 76·74 | 8·859 | 9·077 | ·218 |
| Sb $Bi^3$ | A 16·81, B 83·19 | 9·095 | 9·277 | ·182 |
| Sb $Bi^4$ | A 13·17, B 86·83 | 9·276 | 9·391 | ·119 |
| Sb $Bi^5$ | A 10·82, B 89·18 | 9·369 | 9·464 | ·095 |
| 10. *Bismuth and Zinc.* | | | | |
| Bi Zn | | 9·046 | 9·132 | ·086 |
| 11. *Tin and Lead.* | | | | |
| Pb $Sn^5$ | L 26·03, T 73·97 | 8·093 | 8·367 | ·254 |
| Pb $Sn^4$ | L 30·57, T 69·43 | 8·196 | 8·548 | ·352 |
| Pb $Sn^3$ | L 36·99, T 63·01 | 8·418 | 8·823 | ·405 |
| Pb $Sn^2$ | L 46·82, T 53·18 | 8·774 | 9·232 | ·458 |
| Pb Sn | L 63·78, T 36·22 | 9·458 | 9·938 | ·480 |
| Sn $Pb^2$ | T 22·11, L 77·89 | 10·105 | 10·525 | ·420 |
| Sn $Pb^3$ | T 15·91, L 84·09 | 10·421 | 10·783 | ·362 |
| Sn $Pb^4$ | T 12·43, L 87·57 | 10·587 | 10·927 | ·340 |
| Sn $Pb^5$ | T 10·20, L 89·80 | 10·751 | 11·017 | ·266 |
| 12. *Lead and Antimony.* | | | | |
| Sb $Pb^5$ | A 11·08, L 88·92 | 10·556 | 10·919 | ·363 |
| Sb $Pb^4$ | A 13·48, L 86·52 | 10·387 | 10·805 | ·418 |
| Sb $Pb^3$ | A 17·20, L 82·80 | 10·136 | 10·629 | ·493 |

TABLE 73.—DENSITY OF ALLOYS AND AMALGAMS (*continued*).

| ALLOY. | Proportions per cent. by Weight. | Density obtained. | Density calculated. | Difference. |
|---|---|---|---|---|
| 12. *Lead and Antimony* (*continued*). | | | | |
| $SbPb^2$ . . . . . | A 23·68<br>L 76·32 | 9·723 | 10·321 | ·598 |
| Sb Pb . . . . | A 38·39<br>L 61·61 | 8·953 | 9·624 | ·671 |
| $PbSb^2$ . . . . . | L 44·53<br>A 55·47 | 8·330 | 8·959 | ·629 |
| $PbSb^3$ . . . . | L 34·86<br>A 65·14 | 7·830 | 8·355 | ·525 |
| $PbSb^4$ . . . . . | L 28·64<br>A 71·36 | 7·525 | 8·059 | ·534 |
| $PbSb^5$ . . . . | L 24·31<br>A 75·69 | 7·432 | 7·854 | ·422 |

TABLE 74.—STONES: SPECIFIC GRAVITY, WEIGHT AND VOLUME.

| STONES. | Specific Gravity. | Weight of one Cubic Foot. | Cubic Feet per Ton. |
|---|---|---|---|
| | Water=1. | Pounds. | Cubic Ft. |
| Alabaster, calcareous . . | 2·76 | 172·1 | 13·0 |
| ,, gypseous . . . | 2·31 | 144·0 | 15·6 |
| Barytes . . . . . . | 4·45 | 277·5 | 8·07 |
| Basalt . . . . . . | 2·45 to<br>3·00 | 152·8 to<br>187·1 | 14·7 to<br>12·0 |
| Chalk, air-dried . . . | 2·50 | 155 | 14·5 |
| Diamond . . . . . . | 3·50 | ... | ... |
| Flint . . . . . . | 2·63 | 164 | 13·7 |
| Felspar . . . . . . | 2·60 | 162·1 | 13·8 |
| Gneiss . . . . . . | 2·69 | 168 | 13·3 |
| Granite . . . . . . | 2·50 to<br>2·74 | 156 to<br>171 | 14·4 to<br>13·1 |
| Graphite . . . . . | 2·20 | 137·2 | 16·3 |
| Jasper . . . . . . | 2·72 | 169·7 | 13·2 |
| Lias . . . . . . | 2·25 to<br>2·45 | 140·3 to<br>152·8 | 16·0 to<br>14·7 |
| Limestone . . . . . | 1·86 to<br>2·53 | 116 to<br>158 | 19·3 to<br>14·2 |

TABLE 74.—STONES: SPECIFIC GRAVITY, WEIGHT AND VOLUME (*continued*).

| STONES. | Specific Gravity. | Weight of one Cubic Foot. | Cubic Feet per Ton. |
|---|---|---|---|
| | Water=1. | Pounds. | Cubic Ft. |
| Marble :— | | | |
| African | 2·80 | 174·6 | 12·8 |
| British | 2·71 | 169·0 | 13·3 |
| Carrara | 2·72 | 169·6 | 13·2 |
| Egyptian green | 2·67 | 166·5 | 13·5 |
| Florentine | 2·52 | 157·1 | 14·3 |
| French | 2·65 | 165·2 | 13·6 |
| Mica | 2·93 | 183 | 12·2 |
| Oolitic stones | 1·89 to 2·60 | 118 to 162 | 19·0 to 13·8 |
| Ores :— | | | |
| Spicular or red iron ore | 5·21 | 327·4 | 6·84 |
| Magnetic iron ore | 5·09 | 317·6 | 7·05 |
| Brown iron ore | 3·92 | 244·6 | 9·16 |
| Spathic iron ore | 3·83 | 238·8 | 9·38 |
| Clydesdale iron ore | 3·05 | 190·5 | 11·76 |
| Potter's stone | 2·80 | 174·6 | 12·8 |
| Quartz | 2·61 to 2·71 | 162·8 to 169 | 13·8 to 13·3 |
| „ broken up and heaped | 1·96 | 122 | 20 |
| „ quarry débris | 1·47 | 91·4 | 24·5 |
| Rock crystal | 2·65 | 165·4 | 13·6 |
| Sandstone | 2·04 to 2·70 | 127 to 168 | 17·6 to 13·3 |
| Serpentine | 2·81 | 175·2 | 12·8 |
| Slate | 2·60 to 2·85 | 162·1 to 177·7 | 13·8 to 12·6 |
| Talc, steatite | 2·70 | 168·4 | 13·3 |
| Trap, touchstone | 2·72 | 169·6 | 13·2 |
| **ARTIFICIAL STONES.** | | | |
| Apoenite :—Ransom's silicious stone (silica, soda, water) | 1·60 | 99·7 | 22·5 |
| Concrete :— | | | |
| Portland cement 1, and shingle 10 | 2·23 | 139 | 16·1 |
| Portland cement, rubble, and sand | 2·17 to 2·25 | 135 to 140 | 16·6 to 16·0 |

TABLE 74.—STONES: ARTIFICIAL STONES (*continued*).

| | | | |
|---|---|---|---|
| Concrete :—(*continued*). | | | |
| Portland cement 1, and sand 2 . . . . . | 2·04 | 127 | 17·6 |
| Roman cement 1, and sand 2 . . . . . | 1·92 | 120 | 18·7 |
| Victoria stone (crushed granite, Portland cement, silica) . | 2·31 | 144 | 15·6 |

TABLE 75.—WEIGHT AND COMPOSITION OF BUILDING STONES.

(Gwilt.)

| STONES. | Weight of One Cubic Foot. |
|---|---|
| **1. GRANITES.** | Pounds. |
| Stirling Hill, Stirling . . . . . . . | 165·9 |
| High Rock, Breadalbane . . . . . . | 166·0 |
| Black Hill, Stirling . . . . . . . | 166·6 |
| Dalkey, Dublin . . . . . . . . | 169·6 |
| Bars, Breadalbane . . . . . . . | 169·7 |
| Haytor, Devonshire . . . . . . . . | 165·2 |
| Blue Penmaenmaur, Carnarvonshire . . | 160·1 |
| Aberdeen Grey, Aberdeenshire . . . . | 166·5 |
| ,, Red ,, . . . . | 165·3 |
| Cornish Grey, Cornwall . . . . . . | 166·7 |
| ,, Red ,, . . . . . . | 164·0 |
| Average . . . . . | 166·0 |
| **2. LIMESTONES.** | |
| Beer, Devonshire . . . . . . . . . | 131·7 |
| Chilmark, Wiltshire . . . . . . . . | 153·4 |
| Hopton Wood, Derbyshire . . . . . . | 158·4 |
| Sea Combe, Dorsetshire . . . . . . . | 151·0 |
| Sutton, Glamorganshire . . . . . . | 136·0 |
| Tottenhoe, Bedfordshire . . . . . . . | 116·5 |
| Average . . . . | 141·2 |
| **3. MAGNESIAN LIMESTONES.** | |
| Bolsover, Denbigh . . . . . . . . | 151·7 |
| Broadsworth, Yorkshire . . . . . . . | 133·6 |
| Cadeby ,, . . . . . . . | 126·6 |

TABLE 75.—WEIGHT AND COMPOSITION OF BUILDING STONES (*continued*).

| Stones. | Weight of One Cubic Foot. |
|---|---|
| 3. MAGNESIAN LIMESTONES (*continued*). | |
| Huddlestone ,, | 137·8 |
| Roche Abbey ,, | 139·1 |
| Smawes ,, | 127·5 |
| Average | 136·0 |
| 4. OOLITIC STONES. | |
| Ancaster, Lincolnshire | 139·2 |
| Barnack Mill, Northamptonshire | 136·7 |
| Bath Lodge Hill, Somersetshire | 116·0 |
| Bath Baynton ,, | 123·0 |
| Bath (Drew's Quarry) ,, | 122·6 |
| Cranmore, Wiltshire | 134·2 |
| Haydon, Lincolnshire | 133·5 |
| Ketton, Rutlandshire | 128·3 |
| Portland | 126·8 to 147·6 |
| Taynton, Oxon | 135·9 |
| Wass, Yorkshire | soft, 141·7<br>hard, 162·5 |
| Windrush, Gloucestershire | soft, 118·1<br>hard, 135·9 |
| Average | 133·5 |
| 5. SANDSTONES. | |
| Abercarne, Monmouth | 167·9 |
| Barbadoes, Tintern, Monmouth | 146·7 |
| Binnie, Linlithgowshire | 140·1 |
| Bolton's Quarry, Yorkshire | 126·7 |
| Bramley Fall ,, | 142·2 |
| Calverley, Kent | 118·1 |
| Craigleith, Edinburgh | 145·9 |
| Craw Bank, Linlithgowshire | 129·1 |
| Duffield, Derbyshire | 132·9 |
| Duke's Quarries, Derbyshire | 144·5 |
| Elland Edge, Yorkshire | 153·2 |
| Gatherley Moor ,, | 135·8 |
| Gatton, Surrey | 103·1 |
| Glammis, Forfarshire | 161·1 |
| Heddon, Northumberland | 130·7 |
| Hollington, Staffordshire | 133·1 |
| Humbie, Linlithgow | white, 140·2<br>grey, 135·8 |

TABLE 75.—WEIGHT AND COMPOSITION OF BUILDING STONES (*continued.*)

| STONES. | Weight of One Cubic Foot. |
|---|---|
| 5. SANDSTONES (*continued*). | |
| Longannet, Perthshire . . . . . . . | 131·7 |
| Munlochy, Ross-shire . . . . . . . | 160·6 |
| Mylnefield, Perthshire . . . . . . | 160·0 |
| Park Spring, Yorkshire . . . . . . | 151·1 |
| Pensher, Durham . . . . . . . . | 134·3 |
| Pyot Dykes, Forfarshire . . . . . | 162·5 |
| Scotgate, Yorkshire . . . . . . . | 158·0 |
| Stancliff, Derbyshire . . . . . . | 148·2 |
| Stenton, Durham . . . . . . . . | 142·5 |
| Whitby Company's, Aislaby, Yorkshire . | 126·7 |
| „ Egton „ . . . | 127·9 |
| „ Sneaton „ . . . | 134·8 |
| „ Newton Dale „ . . | 131·7 |
| Average . . . . | 140·5 |
| 6. MARBLES. | |
| Black, Kilkenny . . . . . . . . . | 171·4 |
| Tiree, Hebrides . . . . . . . . | 172·3 |
| Carrara (Statuary), Tuscany . . . . | 168·6 |
| „ Ravaccione . . . . . . . . | 169·1 |
| Ipplepen, Devonshire . . . . . . | 163·4 |
| Average . . . . . | 169·0 |

*General Composition of the above Stones.*

| STONES. | Carbonate of Lime. | Magnesia. | Silica. | Iron, Alumina, Water, and Loss. | Total. |
|---|---|---|---|---|---|
| | Per cent. | Pr.cent. | Pr.cent. | Per cent. | |
| Limestones . | 81·0 | 4·2 | 5 | 9·8 | 100·0 |
| Do. Magnesian | 54·6 | 40·6 | 2 | 2·8 | 100·0 |
| Oolitic Stones . | 94·0 | 2·7 | ... | 3·3 | 100·0 |
| Sandstones . . | 1·1 | ... | 95·5 | 3·4 | 100·0 |
| Marbles . . | lime 56·5, carbonic acid 43·0 | ... | ... | water ·5 | 100·0 |

TABLE 76.—BRICKS: DIMENSIONS AND WEIGHT.
(Hawkes.)

| BRICKS. | Dimensions. | | | Weight of one brick. | Weight per 1000 bricks. |
|---|---|---|---|---|---|
| | In. × | In. × | In. | Pounds. | Cwts. |
| London Stocks | $8\frac{3}{4}$ | $4\frac{1}{4}$ | $2\frac{3}{4}$ | 6·81 | 60·75 |
| Red Kiln | $8\frac{3}{4}$ | $4\frac{1}{4}$ | $2\frac{3}{4}$ | 7·00 | 63 |
| Welsh Fire | 9 | $4\frac{1}{2}$ | $2\frac{3}{4}$ | 7·84 | 65 to 75 |
| Paving | 9 | $4\frac{1}{2}$ | $1\frac{3}{4}$ | 5·00 | 45 |
| Dutch Clinkers | $6\frac{1}{4}$ | 3 | $1\frac{1}{2}$ | 1·55 | 14 |
| Irish Fire | $8\frac{3}{4}$ | $4\frac{1}{8}$ | $2\frac{5}{8}$ | 7·50 | 67 |
| Worcester, solid, machine made | ... | | | 8·75 | 78 |
| Do. perforated | ... | | | 6·00 | 53·5 |
| Staffordshire, solid, hand made | ... | | | 9·50 | 85 |
| London stock, hand made | ... | | | 5·75 | 51 |

TABLE 77.—MINERAL SUBSTANCES, VARIOUS: SPECIFIC GRAVITY, WEIGHT, AND VOLUME.

| SUBSTANCE. | Specific Gravity. | Weight of one Cubic Foot. | Cubic Feet per Ton. |
|---|---|---|---|
| | Water=1. | Pounds. | Cubic Ft. |
| Alum | 1·72 | 107·2 | 20·9 |
| Asphalte | 1·40 | 87·3 | 25·6 |
| Ballast (brick rubbish and gravel) | 1·80 | 112 | 20·0 |
| Brick | 2·00 to 2·17 | 124·7 to 135·3 | 18·1 to 16·0 |
| Brickwork | 1·76 to 1·84 | 110 | 20·4 to 18 |
| Camphor | ·99 | 61·7 | 36·3 |
| Clay | 1·92 | 119·7 | 18·7 |
| Coal:— | | | |
| Anthracite | 1·37 to 1·59 | 85·4 to 99·1 | 26·2 to 22·6 |
| Bituminous | 1·20 to 1·31 | 74·8 to 81·7 | 30 to 28·1 |
| Boghead (Cannel) | 1·20 | 78·4 | 30 |

TABLE 77.—MINERAL SUBSTANCES, VARIOUS: SPECIFIC GRAVITY, WEIGHT, AND VOLUME (*continued*).

| SUBSTANCE. | Specific Gravity. | Weight of One Cubic Foot. | Cubic Feet per Ton. |
|---|---|---|---|
| | Water=1. | Pounds. | Cubic Ft. |
| Earth, argillaceous:— | | | |
| Dry, loose | 1·15 to 1·29 | 72 to 80 | 31·1 to 28 |
| Dry, shaken | 1·32 to 1·48 | 82 to 92 | 27·3 to 24·3 |
| Moist, loose | 1·06 to 1·22 | 66 to 76 | 34·0 to 29·5 |
| Packed | 1·44 to 1·60 | 90 to 100 | 24·8 to 22·4 |
| Light vegetable | 1·40 | 87·3 | 25·7 |
| Glass:— | | | |
| Flint | 3·00 | 187·0 | 12·0 |
| Green | 2·70 | 168·4 | 13·3 |
| Plate | 2·70 | 168·4 | 13·3 |
| Thick flooring | 2·53 | 158·0 | 14·2 |
| Crown | 2·50 | 155·9 | 14·4 |
| St. Gobain | 2·49 | 155·3 | 14·4 |
| Common, with base of potash | 2·46 | 153·4 | 14·6 |
| Fine, with base of potash | 2·45 | 152·8 | 14·6 |
| Common, with base of soda | 2·45 | 152·8 | 14·6 |
| Fine, with base of soda | 2·44 | 152·1 | 14·8 |
| Gunpowder, heaped | 1·75 to 1·84 | 109·1 to 114·7 | 20·5 to 19·5 |
| Ice, melting | ·922 | 57·5 | 39 |
| Marl | 1·60 to 1·90 | 99·8 to 118·5 | 22·4 to 18·9 |
| Masonry:— | | | |
| Ashlar granite | 2·37 | 147·5 | 15·2 |
| ,, Limestone, hard | 2·70 | 168·5 | 11·4 |
| ,, ,, semi-hard | 2·42 | 151·9 | 14·8 |
| ,, ,, soft | 2·34 | 145·6 | 15·4 |
| ,, Millstone | 2·01 to 2·51 | 125 to 156·2 | 18·0 to 14·3 |
| ,, Sandstone | 2·61 | 162·5 | 13·2 |
| Rubble, dry | 2·21 | 138 | 16·2 |
| ,, mortar | 2·47 | 154 | 14·6 |
| Mortar, hardened | 1·65 | 103 | 21·7 |

TABLE 77.—MINERAL SUBSTANCES, VARIOUS: SPECIFIC GRAVITY, WEIGHT, AND VOLUME (*continued*).

| SUBSTANCE. | Specific Gravity. | Weight of One Cubic Foot. | Cubic Foot per Ton. |
|---|---|---|---|
| | Water=1. | Pounds. | Cubic Ft. |
| Mud :— | | | |
| Dry, close | 1·28 to 1·93 | 80 to 110 | 28·0 to 20·4 |
| Wet, moderately pressed | 1·93 to 2·09 | 110 to 130 | 20·4 to 17·2 |
| Wet, fluid | 1·67 to 1·92 | 104 to 120 | 21·5 to 18·7 |
| Phosphorus | 1·77 | 110·4 | 20·3 |
| Plaster | 1·57 | 98 | 22·9 |
| Portland cement | 1·25 to 1·51 | 78 to 94 | 28·7 to 23·8 |
| Potash | 2·10 | 131 | 17·1 |
| Sand | 1·44 to 1·87 | 90 to 117 | 24·9 to 19·1 |
| „ saturated with water | 1·89 to 2·07 | 118 to 129 | 19 to 17·4 |
| Salt, common | 1·92 | 119·7 | 18·7 |
| „ rock | 2·10 to 2·26 | 131 to 140·7 | 17·1 to 15·9 |
| Sulphur | 2·00 | 124·7 | 18·0 |
| Tiles | 2·00 | 124·7 | 18·0 |

TABLE 77*a*.—FUELS IN FRANCE.

| | Weight of one Cub. Ft. | Specific Gravity. |
|---|---|---|
| | Pounds. | Water=1. |
| Pure graphite | 145·3 | 2·33 |
| Anthracite | 83·5 to 91·0 | 1·34 to 1·46 |
| Rich coal with a long flame | 79·8 to 84·8 | 1·28 to 1·36 |
| Dry coal with a long flame | 84·8 | 1·36 |
| Rich and hard coal | 82·3 | 1·32 |
| Smithy coal | 79·8 to 81·1 | 1·28 to 1·30 |
| Lignite | 77·9 to 84·2 | 1·25 to 1·35 |
| „ bituminous | 72·3 to 74·8 | 1·16 to 1·20 |
| „ imperfect | 81·7 | 1·31 |
| Bitumen, red | 72·3 | 1·16 |
| „ black | 66·7 | 1·07 |
| „ brown | 51·7 | 0·83 |
| [illegible] | 66·1 | 1·06 |

## TABLE 78.—WEIGHT AND VOLUME IN BULK OF VARIOUS SOLIDS.

(Tredgold.)

| SUBSTANCE. | Weight of One Cubic Foot in bulk. | Volume of One Ton in bulk. |
|---|---|---|
| | Pounds. | Cubic Feet. |
| Lead, cast in pigs | 567 | 4 |
| Iron, cast in pigs | 360 | 6·25 |
| Limestone or Marble, in blocks | 172 | 13 |
| Granite, Aberdeen, in blocks | 166 | 13·5 |
| " Cornish, " | 164 | 14 |
| Sandstone, in blocks | 141 | 16 |
| Portland Stone, in blocks | 132 | 17 |
| Potter's Clay | 130 | 17 |
| Loam or Strong Soil | 126 | 18 |
| Bath Stone, in blocks | 123·5 | 18 |
| Gravel | 109 | 21 |
| Sand | 95 | 23·5 |
| Bricks, Common Stock, dry | 93 | 24 |
| Culm | 63 | 36 |
| Water, River | 62·5 | 36 |
| Splint Coal | 57 | 39·5 |
| Oak, Seasoned | 52 | 43 |
| Coal (Newcastle) coking | 50 | 45 |
| Wheat | 48 | 47 |
| Barley | 38 | 59 |
| Red Fir | 38 | 59 |
| Hay, compact, old | 8 | 280 |

## TABLE 79.—MEASURES OF ORES, EARTH, &C.

(Rand Drill Company.)

| | | | Weight. |
|---|---|---|---|
| 14·5 | Cubic Feet | of ordinary Gold or Silver Ore, in mine | 1 ton |
| 22 | " | of Broken Quartz | 1 " |
| 20 | " | Gravel, in bank | 1 " |
| 30 | " | Gravel, when dry | 1 " |
| 28 | " | Sand | 1 " |
| 20 | " | Earth, in bank | 1 " |
| 30 | " | " " when dry | 1 " |
| 19 | " | Clay | 1 " |
| 45 | " | Bituminous Coal, heaped | 1 " |
| 42 | " | Anthracite " | 1 " |
| 123 | " | Charcoal " | 1 " |
| 71 | " | Coke " | 1 " |

| | | Weight. |
|---|---|---|
| 1 Cubic Foot | Anthracite, heaped . . | 50 lb. to 55 lb. |
| 1 ,, | Bituminous Coal ,, . . . | 45 lb. to 55 lb. |
| 1 ,, | Cumberland Coal . . . | 53 lb. |
| 1 ,, | Cannel Coal . . . . . | 50¼ lb. |
| 1 ,, | Hardwood Charcoal . . | 18½ lb. |
| 1 ,, | Pine Charcoal . . . . | 18 lb. |

| | Weight. | Equivalent as Fuel to |
|---|---|---|
| 1 Cord of Wood, 4 feet × 4 feet × 8 feet . | | = 128 cubic feet |
| 1 Cord of air-dried Hickory or Hard Maple . . | 4,500 lb. | 2,000 lb. coal. |
| 1 ,, ,, White Oak . . . | 3,850 ,, | 1,715 ,, |
| 1 ,, ,, Beech, Red Oak or Black Oak . | 3,250 ,, | 1,450 ,, |
| 1 ,, ,, Poplar (white wood), Chestnut, or Elm . | 2,350 ,, | 1,050 ,, |
| 1 ,, ,, Average Pine . | 2,000 ,, | 925 ,, |

TABLE 80.—FUELS: SPECIFIC GRAVITY, WEIGHT, AND BULK.

| FUELS. | Specific Gravity. | Weight of One Cubic Foot. | | Volume of One Ton, heaped |
|---|---|---|---|---|
| | | Solid. | Heaped. | |
| | Water = 1. | Lbs. | Lbs. | Cub. Ft. |
| **COALS.** | | | | |
| Anthracite . . . . . | 1·37 | 85·4 | 58·3 | 38·4 |
| ,, American . . | 1·30 to 1·84 | 93·5 | 54·0 | ... |
| Welsh . . . . . | 1·32 | 82·3 | 53·1 | 42·7 |
| Newcastle . . . . . | 1·25 | 78·3 | 49·8 | 45·3 |
| Derbyshire and Yorkshire . | 1·29 | 79·6 | 45·9 | 47·4 |
| Lancashire . . . . . | 1·27 | 79·4 | 49·7 | 45·2 |
| Scotch . . . . . . | 1·26 | 78·6 | 50·0 | 42·0 |
| Irish: Slievardagh anthracite . . . . . | 1·59 | 99·6 | 62·8 | 35·7 |
| Bituminous coal, American | 1·35 | 84·0 | 50·0 | ... |
| Boghead (Scotland) . . | 1·18 | ... | ... | ... |
| **COKE.** | | | | |
| Coke, generally . . . | ... | 40 to 50 | 30·0 | 70 to 80 |
| Solid . . . . . . | ·74 | 46 | 30·0 | 74·7 |

TABLE 80.—FUELS: SPECIFIC GRAVITY, WEIGHT, AND BULK (*continued*).

| Fuels. | Specific Gravity. | Weight of One Cubic Foot. Solid. | Weight of One Cubic Foot. Heaped. | Volume of One Ton, heaped. |
|---|---|---|---|---|
| | Water=1. | Lbs. | Lbs. | Cub. Ft. |
| COKE (*continued*). | | | | |
| Gas coke | ... | ... | 23·8 to 28·6 | ... |
| American | ... | ... | 32·1 | 69·8 |
| Seraing (France) | ... | ... | 31·0 | 72·0 |
| Graphite | 2·33 | 145·3 | ... | ... |
| LIGNITE AND ASPHALTE. | | | | |
| Perfect lignite | 1·29 | ... | ... | ... |
| Imperfect lignite | 1·15 | ... | ... | ... |
| Bituminous lignite | 1·18 | ... | ... | ... |
| Asphalte | 1·06 | ... | ... | ... |
| WOOD.—*See* Table 81. | | | | |
| WOOD CHARCOAL. *As made, heaped.* | Heaped. | | | |
| Oak and beech | ·24 to ·25 | ... | 15 to 15·6 | ... |
| Birch | ·22 to ·23 | ... | 13·7 to 14·3 | ... |
| Pine | ·20 to ·21 | ... | 12·5 to 13·1 | ... |
| Average | ·225 | ... | 14 | ... |
| *In small pieces, heaped.* | | | | |
| Walnut | ·63 | ... | 39·3 | ... |
| Ash | ·53 | ... | 34·3 | ... |
| Beech | ·52 | ... | 32·5 | ... |
| Yoke-Elm | ·46 | ... | 28·7 | ... |
| Appleton | ·46 | ... | 28·7 | ... |
| White oak | ·42 | ... | 26·2 | ... |
| Cherry tree | ·41 | ... | 25·6 | ... |
| Birch | ·36 | ... | 22·5 | ... |
| Elm | ·36 | ... | 22·5 | ... |
| Yellow pine | ·33 | ... | 20·6 | ... |
| Chestnut tree | ·28 | ... | 17·5 | ... |
| Poplar | ·25 | ... | 15·6 | ... |
| Cedar | ·24 | ... | 15·0 | ... |
| Average | ·405 | ... | 25·3 | ... |

TABLE 80.—FUELS: SPECIFIC GRAVITY, WEIGHT, AND BULK (*continued*).

| Fuels. | Specific Gravity. | Weight of One Cubic Foot. | | Volume of One Ton, heaped. |
|---|---|---|---|---|
| | | Solid. | Heaped. | |
| | Water = 1. | Lbs. | Lbs. | Cub. Ft. |
| *As Powder.* | | | | |
| Willow | 1·55 | ... | 96·7 | ... |
| Oak | 1·53 | ... | 95·4 | ... |
| Alder | 1·49 | ... | 92·9 | ... |
| Lime tree | 1·46 | ... | 91·0 | ... |
| Poplar | 1·45 | ... | 90·4 | ... |
| Average | 1·50 | ... | 93·5 | ... |
| Gunpowder, loose | ·90 | ... | ... | ... |
| " shaken | 1·00 | ... | ... | ... |
| " solid | 1·55 to 1·80 | ... | ... | ... |
| *Irish Peat.* | | | | |
| Very light, spongy, surface peat | ·22 to ·34 | 13·7 to 21·0 | ... | ... |
| Light surface peat | ·34 to ·41 | 20·9 to 25·3 | ... | ... |
| Rather dense | ·48 to ·67 | 29·7 to 41·7 | ... | ... |
| Very dense, dark brown | ·65 to ·71 | 40·5 to 44·5 | ... | ... |
| Very dense, blackish brown, compact | ·72 to ·98 | 45·1 to 61·3 | ... | ... |
| Exceedingly dense, jet black | ·73 to ·99 | 53·2 to 61·8 | ... | ... |
| Exceedingly dense, dark blackish brown | 1·05 | 66·0 | ... | ... |
| Upper moss | ... | ... | 6·06 to 8·81 | 369·6 to 254·2 |
| Brown | ... | ... | 15·13 | 147·0 |
| Compact black | ... | ... | 17·06 | 131·3 |
| Densest black | ... | ... | 22·54 | 99·4 |
| Condensed peat | 1·0 to 1·3 | 62·5 to 81·1 | 43·7 to 56·8 | 51·2 to 40·0 |

TABLE 81.—WOODS: SPECIFIC GRAVITY AND WEIGHT.

| Wood. | Specific Gravity. | Weight of One Cubic Foot. |
|---|---|---|
| | Water=1. | Pounds. |
| Acacia | ·82 | 51·1 |
| „ with 20 per cent. moisture | ·72 | 44·9 |
| Alder tree | ·56 | 34·9 |
| „ with 20 per cent. moisture | ·60 | 37·4 |
| Ash | ·84 | 52·4 |
| „ with 20 per cent. moisture. | ·70 | 43·7 |
| Aspen tree | ·60 | 37·4 |
| Apple tree | ·73 | 45·5 |
| Bamboo | ·31 to ·40 | 19·5 to 24·9 |
| Beech | ·75 to ·85 | 46·8 to 50·3 |
| „ with 20 per cent. moisture | ·82 | 51·1 |
| „ cut one year | ·66 | 41·2 |
| Birch | ·72 to ·74 | 44·9 to 46·1 |
| Boxwood | 1·04 | 64·8 |
| Cedar of Lebanon | ·49 to ·57 | 30·6 to 35·5 |
| Cork | ·24 | 15·0 |
| Cypress, cut one year | ·66 | 41·2 |
| Ebony | 1·13 | 70·5 |
| „ Green | 1·21 | 75·5 |
| „ Black | 1·19 | 74·2 |
| Elder pith | ·076 | 4·74 |
| Elm | ·55 | 34·3 |
| „ Green | ·76 | 47·5 |
| „ with 20 per cent. moisture | ·72 | 44·9 |
| Fir, Norway Pine | ·74 | 46·1 |
| „ Red Pine | ·48 to ·70 | 29·9 to 43·7 |
| „ Spruce | ·48 to ·70 | 29·9 to 43·7 |
| „ Larch | ·50 to ·64 | 31·2 to 39·9 |
| „ White Pine, English | ·55 | 34·3 |
| „ „ Scotch | ·53 | 34·3 |
| „ „ „ with 20 per cent. moisture | ·49 | 30·6 |
| „ Yellow Pine | ·66 | 41·2 |
| „ „ American | ·46 | 28·7 |
| Hawthorn | ·91 | 56·7 |
| Holly | ·76 | 47·5 |
| Hornbeam | ·76 | 47·5 |
| Laburnum | ·92 | 57·4 |
| Lance Wood | ·67 to 1·01 | 41·8 to 63·0 |
| Lignum-Vitæ | ·65 to 1·33 | 40·5 to 82·9 |

TABLE 81.—WOODS: SPECIFIC GRAVITY AND WEIGHT (*continued*).

| Wood. | Specific Gravity. | Weight of One Cubic Foot. |
|---|---|---|
| | Water = 1. | Pounds. |
| Mahogany, Spanish | ·85 | 53·0 |
| „ St. Domingo | ·75 | 46·8 |
| „ Cuba | ·56 | 34·9 |
| „ Honduras | ·56 | 34·9 |
| Maple | ·65 | 40·5 |
| „ 20 per cent. moisture | ·67 | 41·8 |
| Mulberry | ·89 | 55·5 |
| Oak, Heart of | 1·17 | 73·0 |
| „ English | ·93 | 58·0 |
| „ European | ·69 to ·99 | 43·0 to 61·7 |
| „ American Red | ·87 | 54·2 |
| Olive tree | ·68 | 42·4 |
| Orange tree | ·71 | 44·3 |
| Pear tree | ·73 | 45·5 |
| Plane tree | ·65 | 40·5 |
| Plum tree | ·87 | 54·2 |
| Pomegranate | 1·35 | 84·2 |
| Poplar | ·39 | 24·3 |
| „ White | ·32 to ·51 | 20·0 to 31·8 |
| „ 20 per cent. moisture | ·48 | 29·9 |
| Rosewood | 1·03 | 64·2 |
| Rock-Elm | ·80 | 50·0 |
| Satin-wood | ·96 | 59·9 |
| Service tree | ·67 | 41·8 |
| Sycamore | ·59 | 36·8 |
| Teak, African | ·98 | 61·0 |
| Vine tree | ·60 | 37·4 |
| Walnut, Green | ·92 | 57·4 |
| „ Brown | ·68 | 42·4 |
| Willow | ·49 | 30·6 |
| Yew | ·74 to ·81 | 46·1 to 50·5 |
| Yoke Elm, with 20 per cent. moisture | ·76 | 47·5 |
| INDIAN WOODS (Berkley). | | |
| Khair | 1·17 | 73 |
| Red Eyne | 1·09 | 68 |
| Erroul | 1·01 | 63 |
| [illegible] | ·90 | 56 |

TABLE 81.—WOODS: SPECIFIC GRAVITY AND WEIGHT (*continued*).

| Wood. | Specific Gravity. | Weight of One Cubic Foot. |
|---|---|---|
| | Water=1. | Pounds. |
| INDIAN WOODS (*continued*). | | |
| Blackwood | ·90 | 56 |
| Northern Teak | ·88 | 55 |
| Southern Teak | ·77 | 48 |
| Jungle Teak | ·66 | 41 |
| Kullum | ·66 | 41 |
| Hedoo | ·63 | 39 |
| Poon | ·63 | 39 |
| BRITISH GUIANA (Fowke). | | |
| Sipiri, or Green Heart | 1·05 to 1·09 | 65·5 to 68·0 |
| Wallaba | 1·04 | 64·8 |
| Brown Ebony | 1·03 | 64·2 |
| Letter Wood | 1·00 | 62·4 |
| Cuamara, or Tonka | ·99 | 61·7 |
| Monkey Pot | ·94 | 58·6 |
| Mora | ·92 | 57·4 |
| Ducaballi | ·91 | 56·7 |
| Cabacalli | ·89 | 55·5 |
| Kaieeballi | ·87 | 54·2 |
| Sirabuliballi | ·84 | 52·4 |
| Buhuradda | ·81 | 50·5 |
| Buckati | ·81 | 50·5 |
| Houbaballi | ·81 | 50·5 |
| Baracara | ·81 | 50·5 |
| White Cedar | ·77 | 48·0 |
| Locust tree | ·71 | 44·3 |
| Cartan | ·70 | 43·7 |
| Purple Heart | ·68 | 42·4 |
| Bartaballi | ·64 | 39·4 |
| Crabwood | ·60 | 37·4 |
| Silverballi | ·55 | 34·3 |
| JAMAICA (Fowke). | | |
| Black Heart Ebony | 1·19 | 74·2 |
| Lignum-Vitæ | ·65 to 1·17 | 40·5 to 73·0 |
| Small Leaf | 1·17 | 73·0 |
| Neesberry Bullet tree | 1·05 | 65·5 |
| Red Bully tree | 1·00 | 62·4 |
| Iron Wood | ·99 | 61·7 |
| Sweet Wood | ·97 | 60·5 |

TABLE 81.—WOODS: SPECIFIC GRAVITY AND WEIGHT (*continued*).

| Wood. | Specific Gravity. | Weight of One Cubic Foot. |
|---|---|---|
| | Water=1. | Pounds. |
| JAMAICA (*continued*). | | |
| Fustic | ·97 | 60·5 |
| Satin Candlewood | ·96 | 59·9 |
| Bastard Cabbage Bark | ·94 | 58·6 |
| White Dogwood | ·94 | 58·6 |
| Black ,, | ·93 | 58·0 |
| Gynip | ·93 | 58·0 |
| Wild Mahogany | ·92 | 57·4 |
| Cashaw | ·92 | 57·4 |
| Wild Orange | ·85 to ·91 | 53·0 to 56·7 |
| Sweet Orange | ·79 | 49·3 |
| Bullet tree (bastard) | ·90 | 56·1 |
| Tamarind | ·87 | 54·2 |
| ,, wild | ·75 | 46·8 |
| Prune | ·86 | 53·6 |
| Yellow Sanders | ·86 | 53·6 |
| Beech | ·84 | 52·4 |
| French Oak | ·77 | 48·0 |
| Broad Leaf | ·77 | 48·0 |
| Fiddlewood | ·71 | 44·3 |
| Prickle Yellow | ·69 | 43·0 |
| Boxwood | ·69 | 43·0 |
| Locust tree | ·68 | 42·4 |
| Lance Wood | ·68 | 42·4 |
| Green Mahogany | ·66 | 41·2 |
| Yacca | ·63 | 39·3 |
| Cedar | ·58 | 36·2 |
| Calabash | ·56 | 34·9 |
| Bitter Wood | ·55 | 34·3 |
| Blue Mahoe | ·54 | 33·7 |
| NEW SOUTH WALES. | | |
| Box of Ilwarra | 1·17 | 73·0 |
| ,, Bastard | 1·12 | 69·8 |
| ,, True, of Camden | ·97 | 60·5 |
| Mountain Ash | 1·11 | 69·2 |
| Kakaralli | 1·10 | 68·6 |
| Iron Bark | 1·03 | 64·2 |
| ,, broad leaved | 1·02 | 63·6 |
| [illegible]lly Butt | 1·01 | 63·0 |
| ,, | ·89 | 55·5 |

TABLE 81.—WOODS: SPECIFIC GRAVITY AND WEIGHT (*continued*).

| Wood. | Specific Gravity. | Weight of One Cubic Foot. |
|---|---|---|
| | Water=1. | Pounds. |
| NEW SOUTH WALES (*continued*). | | |
| Water Gum | 1·00 | 62·4 |
| Blue Gum | ·84 | 52·4 |
| Cog Wood | ·96 | 59·9 |
| Mahogany | ·95 | 59·2 |
| " Swamp | ·86 | 53·6 |
| Gray Gum | ·93 | 58·0 |
| Stringy Bark | ·86 | 53·6 |
| Hickory | ·75 | 46·8 |
| Forest Swamp Oak | ·66 | 41·2 |

TABLE 82.—ANIMAL SUBSTANCES: SPECIFIC GRAVITY AND WEIGHT.

(Claudel.)

| Substance. | Specific Gravity. | Weight of One Cubic Foot. |
|---|---|---|
| | Water=1. | Pounds. |
| Pearls | 2·72 | 169·6 |
| Coral | 2·69 | 167·7 |
| Ivory | 1·82 to 1·92 | 114 to 119·7 |
| Bone | 1·80 to 2·00 | 112·2 to 124·7 |
| Wool | 1·61 | 100·4 |
| Tendon | 1·12 | 69·8 |
| Cartilage | 1·09 | 68·0 |
| Crystalline humour | 1·08 | 67·3 |
| Human Body | 1·07 | 66·7 |
| Nerve | 1·04 | 64·9 |
| Bees Wax | ·96 | 59·9 |
| Lard | ·95 | 59·3 |
| Spermaceti | ·94 | 58·8 |
| White of Whalebone | ·94 | 58·7 |
| Butter | ·94 | 58·7 |
| Pork Fat | ·94 | 58·7 |
| Tallow | ·92 | 57·5 |
| Beef Fat | ·92 | 57·5 |
| Mutton Fat | ·92 | 57·4 |
| Animal Charcoal, in heaps | ·80 to ·83 | 50 to 52 |

TABLE 83.—VEGETABLE SUBSTANCES: SPECIFIC GRAVITY AND WEIGHT.

| SUBSTANCE. | Specific Gravity. | Weight of One Cubic Foot. |
|---|---|---|
| | Water=1. | Pounds. |
| Cotton | 1·95 | 121·6 |
| Flax | 1·79 | 111·6 |
| Starch | 1·53 | 95·4 |
| Fecula | 1·50 | 93·5 |
| Gum, Arabic | 1·45 | ... |
| " Mastic | 1·07 | 66·7 |
| Resin, Guayacum | 1·20 | 74·8 |
| " Benzoin | 1·09 | 68·0 |
| Indigo | 1·009 | ... |
| Sugar | 1·005 | ... |
| Amber | 1·09 | 68·0 |
| Gutta-percha | ·97 | 60·5 |
| India-rubber | ·93 | 58·0 |
| | Weight of One Cubic Foot, loosely filled. | Weight of One Cubic Foot, closely filled. |
| Grain:— | | |
| Wheat, Red Winter | 49 | 53½ |
| " Bombay | 49 | 53 |
| " California | 49 | 53 |
| " Walla-Walla | 46 | 50½ |
| " Bessarabia | 49 | 53 |
| Peas, American | 50 | 54 |
| Indian Corn, White American | 43½ | 47 |
| " Mixed | 44 | 47 |
| Oats, Russian | 28 | 33 |
| Beans, Egyptian | 46 | 50 |
| Barley, English | 39 | 44 |

*Note.*—Under the Corn Returns Act, 1882, the bushel of the following grains is, for statistical purposes, to be taken respectively:—

For Wheat as . . . . . . . 60 lb.
For Barley as . . . . . . . 50 lb.
For Oats as . . . . . . . 39 lb.

TABLE 84.—LIQUIDS:—SPECIFIC GRAVITY AND WEIGHT.

| LIQUIDS AT 32° F. | Specific Gravity. | Weight of One Cubic Foot. | Weight of One Gallon. |
|---|---|---|---|
| | Water = 1. | Pounds. | Pounds. |
| Mercury | 13·596 | 848·7 | 136·0 |
| Sulphuric Acid, maximum concentration | 1·84 | 114·9 | 18·4 |
| Nitrous Acid | 1·55 | 96·8 | 15·5 |
| Chloroform | 1·53 | 95·5 | 15·3 |
| Nitric acid, of commerce | 1·22 | 76·2 | 12·2 |
| Acetic acid, maximum concentration | 1·08 | 67·4 | 10·8 |
| Milk | 1·03 | 64·3 | 10·3 |
| Sea Water, ordinary | 1·026 | 64·05 | 10·3 |
| Pure Water, at 39·0° F. | 1·000 | 62·425 | 10·0112 |
| Wine, Red | ·99 | 62·0 | 9·9 |
| Oil, Linseed | ·94 | 58·7 | 9·4 |
| „ Rapeseed | ·92 | 57·4 | 9·2 |
| „ Whale | ·92 | 57·4 | 9·2 |
| „ Olive | ·915 | 57·1 | 9·15 |
| „ Turpentine | ·87 | 54·3 | 8·7 |
| Tar | 1·00 | 62·4 | 10·0 |
| Petroleum | ·88 | 54·9 | 8·8 |
| Naphtha | ·85 | 53·1 | 8·5 |
| Ether, Nitric | 1·11 | 69·3 | 11·1 |
| „ Sulphurous | 1·08 | 67·4 | 10·8 |
| „ Nitrous | ·89 | 55·6 | 8·9 |
| „ Acetic | ·89 | 55·6 | 8·9 |
| „ Hydrochloric | ·87 | 54·3 | 8·7 |
| „ Sulphuric | ·72 | 44·9 | 7·2 |
| Alcohol, proof spirit | ·92 | 57·4 | 9·2 |
| „ pure | ·79 | 49·3 | 7·9 |
| Benzine | ·85 | 53·1 | 8·5 |
| Proof Spirit | ·80 | 49·9 | 8·0 |

TABLE 85.—WEIGHT AND SPECIFIC GRAVITY OF OILS. (Stilwell.)

| OILS AT 39° F. | Weight of One Gallon. | Specific Gravity. |
|---|---|---|
| | Pounds. | Water = 1. |
| Sperm, bleached, winter | 8·81 | ·881 |
| „ natural, winter | 8·81 | ·881 |
| Elaine | 9·01 | ·901 |
| Red. saponified | 9·02 | ·902 |
| Palm | 9·05 | ·905 |
| Tallow | 9·14 | ·914 |
| Neatsfoot | 9·14 | ·914 |
| Rape-seed, white, winter | 9·14 | ·914 |
| Olive, light greenish yellow | 9·14 | ·914 |
| „ dark green | 9·14 | ·914 |
| Peanut | 9·15 | ·915 |
| Olive, virgin, very light yellow | 9·16 | ·916 |
| Rape-seed, dark yellow | 9·17 | ·917 |
| Olive, virgin, dark clear yellow | 9·17 | ·917 |
| Lard, winter | 9·17 | ·917 |
| Sea Elephant | 9·20 | ·920 |
| Tanner's Cod | 9·20 | ·920 |
| Cotton-seed, raw | 9·22 | ·922 |
| „ refined, yellow | 9·23 | ·923 |
| Salad (cotton-seed) | 9·23 | ·923 |
| Labrador (cod) | 9·24 | ·924 |
| Poppy | 9·24 | ·924 |
| Seal, natural | 9·25 | ·925 |
| Cocoanut | 9·25 | ·925 |
| Whale, natural, winter | 9·25 | ·925 |
| „ bleached, winter | 9·26 | ·926 |
| Codliver, pure | 9·27 | ·927 |
| Seal, racked | 9·29 | ·929 |
| Cotton-seed, white, winter | 9·29 | ·929 |
| Straits (cod) | 9·29 | ·929 |
| Menhaden, dark | 9·29 | ·929 |
| Linseed (raw) | 9·30 | ·930 |
| Bank (cod) | 9·32 | ·932 |
| Menhaden, light | 9·32 | ·932 |
| Porgy | 9·33 | ·933 |
| Linseed, boiled | 9·41 | ·941 |
| Castor, pure cold pressed | 9·67 | ·967 |
| Rosin, third run | 9·89 | ·989 |

TABLE 86.—GASES AND VAPOURS.—SPECIFIC GRAVITY, WEIGHT, AND VOLUME.

| Gases at 32° F., and under one Atmosphere of Pressure. | Specific Gravity. | Weight of One Cubic Foot. | | Volume of One Pound Weight |
|---|---|---|---|---|
| | Air = 1. | Pounds. | Ounces. | Cub. Ft. |
| Mercury | 6·9740 | ·563 | 9·008 | 1·776 |
| Chloroform | 5·3000 | ·428 | 6·846 | 2·337 |
| Turpentine | 4·6978 | ·378 | 6·042 | 2·637 |
| Acetic Ether | 3·0400 | ·245 | 3·927 | 4·075 |
| Benzine | 2·6943 | ·217 | 3·480 | 4·598 |
| Sulphuric Ether | 2·5860 | ·209 | 3·340 | 4·790 |
| Chlorine | 2·4400 | ·197 | 3·152 | 5·077 |
| Sulphurous Acid | 2·2470 | ·1814 | 2·902 | 5·513 |
| Alcohol | 1·6130 | ·1302 | 2·083 | 7·679 |
| Carbonic Acid | 1·5290 | ·12344 | 1·975 | 8·101 |
| Oxygen | 1·1056 | ·089253 | 1·428 | 11·205 |
| Air | 1·0000 | ·080728 | 1·29165 | 12·387 |
| Nitrogen | ·9736 | ·078596 | 1·258 | 12·723 |
| Carbonic Oxide | ·9674 | ·0781 | 1·250 | 12·804 |
| Olefiant Gas | ·9847 | ·0795 | 1·272 | 12·580 |
| Ammoniacal Gas | ·5894 | ·04758 | 7·613 | 21·017 |
| Light Carburetted Hydrogen | ·5527 | ·04462 | ·7139 | 22·412 |
| Coal Gas | ·4381 | ·03536 | ·5658 | 28·279 |
| Hydrogen | ·0692 | ·005592 | ·0895 | 178·83 |

TABLE 87.—WEIGHT AND VOLUME OF BODIES.

(Tod)

| Bodies. | Weight of One Cubic Foot. | | Weight of One Cubic Inch. | Cubic Inches in One Pound. |
|---|---|---|---|---|
| | Oz. | Lb. | Oz. | Cub. In. |
| **METALS.** | | | | |
| Antimony, cast | 6,702 | 418·8750 | 3·8748 | 3·8866 |
| Zinc, cast | 7,190 | 449·3750 | 4·1608 | 3·8431 |
| Iron, cast | 7,207 | 450·4375 | 4·1707 | 3·8364 |
| Tin, cast | 7,291 | 455·6875 | 4·2193 | 3·7920 |
| „ hardened | 7,299 | 456·1875 | 4·2239 | 3·7878 |
| Pewter | 7,471 | 466·9375 | 4·3234 | 3·7007 |

TABLE 87.—WEIGHT AND VOLUME OF BODIES (*continued*).

| Bodies. | Weight of One Cubic Foot. | | Weight of One Cubic Inch. | Cubic Inches in One Pound. |
|---|---|---|---|---|
| | Oz. | Lb. | Oz. | Cub. In. |
| **METALS** (*continued*). | | | | |
| Iron, bar | 7,788 | 486·7500 | 4·5069 | 3·5500 |
| Cobalt, cast | 7,811 | 488·1875 | 4·5202 | 3·5396 |
| Steel, hard | 7,816 | 488·5000 | 4·5231 | 3·5373 |
| „ soft meteoric | 7,833 | 489·5625 | 4·5329 | 3·5296 |
| Iron, hammered | 7,965 | 497·8125 | 4·6093 | 3·4792 |
| Nickel, cast | 8,279 | 517·4375 | 4·7910 | 3·3395 |
| Brass, cast | 8,395 | 524·6875 | 4·8582 | 3·2933 |
| „ wire | 8,544 | 534·0000 | 4·9444 | 3·2359 |
| Nickel, hammered | 8,666 | 541·6250 | 5·0150 | 3·1903 |
| Gun-metal | 8,784 | 549·0000 | 5·0833 | 3·1476 |
| Copper, cast | 8,788 | 549·2500 | 5·0856 | 3·1461 |
| „ wire | 8,878 | 554·8750 | 5·1377 | 3·1140 |
| „ coin | 8,915 | 557·1875 | 5·1591 | 3·0959 |
| Bismuth, cast | 9,822 | 613·8750 | 5·6840 | 2·8149 |
| Silver, hammered | 10,510 | 656·8750 | 6·0821 | 2·6306 |
| „ coin | 10,534 | 658·3750 | 6·0960 | 2·6246 |
| „ pure, cast | 10,744 | 671·5000 | 6·2175 | 2·5733 |
| Rhodium | 11,000 | 687·5000 | 6·3657 | 2·5134 |
| Lead, cast | 11,352 | 709·5000 | 6·3694 | 2·4355 |
| Palladium | 11,800 | 737·5000 | 6·8287 | 2·5134 |
| Mercury (quicksilver) common | 13,568 | 848·0000 | 7·8518 | 2·0377 |
| „ „ pure | 14,000 | 875·0000 | 8·1018 | 1·9748 |
| Gold, trinket | 15,709 | 981·8125 | 9·0908 | 1·7600 |
| „ coin | 17,647 | 1102·9375 | 10·2123 | 1·6124 |
| „ pure, cast | 19,258 | 1203·6250 | 11·1446 | 1·4356 |
| „ hammered | 19,316 | 1210·0625 | 11·2042 | 1·4280 |
| Platinum, pure | 19,500 | 1218·7500 | 11·2847 | 1·4178 |
| „ hammered | 20,336 | 1271·0000 | 11·7685 | 1·3595 |
| „ wire | 21,041 | 1315·0625 | 12·1765 | 1·3140 |
| „ laminated | 22,069 | 1379·3125 | 12·7714 | 1·2528 |
| Iridium, hammered | 23,000 | 1437·5000 | 13·3101 | 1·2021 |
| **EARTH, STONES, &c.** | | | | |
| Amber | 1,078 | 67·3750 | 0·62384 | 25·6474 |
| Coal | 1,250 | 78·7500 | 0·72337 | 21·9428 |
| Sand | 1,500 | 93·7500 | 0·86803 | 18·4320 |
| Brick | 2,000 | 125·0000 | 1·15740 | 13·8240 |

TABLE 87.—WEIGHT AND VOLUME OF BODIES (*continued*).

| BODIES. | Weight of One Cubic Foot. | | Weight of One Cubic Inch. | Cubic Inches in One Pound. |
|---|---|---|---|---|
| | Oz. | Lb. | Oz. | Cub. In. |
| EARTH, STONES, &c. (*continued*). | | | | |
| Sulphur, native | 2,033 | 127·0625 | 1·17650 | 13·5996 |
| Opal | 2,114 | 132·1250 | 1·22337 | 13·0785 |
| Clay | 2,160 | 135·0000 | 1·25000 | 12·8000 |
| Gypsum | 2,280 | 142·5000 | 1·31944 | 12·1263 |
| Porcelain, Limoges | 2,341 | 146·3125 | 1·35474 | 11·8103 |
| ,, China | 2,385 | 147·2500 | 1·38020 | 11·7351 |
| Stone, paving | 2,416 | 151·4000 | 1·39814 | 11·4437 |
| ,, common | 2,520 | 157·5000 | 1·45833 | 10·9714 |
| Flint | 2,594 | 162·1250 | 1·50115 | 10·6584 |
| Spar | 2,594 | 162·1250 | 1·50115 | 10·6584 |
| Pebble, English | 2,619 | 163·6875 | 1·51562 | 10·5566 |
| Granite, Aberdeen | 2,625 | 164·0625 | 1·51909 | 10·5325 |
| Quartz | 2,640 | 165·0000 | 1·52777 | 10·4727 |
| Glass, green | 2,642 | 165·1250 | 1·52893 | 10·4648 |
| Crystal, rock | 2,653 | 165·8125 | 1·53530 | 10·4214 |
| Granite, red Egyptian | 2,654 | 165·8750 | 1·53587 | 10·4175 |
| ,, Cornish | 2,662 | 166·3750 | 1·53935 | 10·3861 |
| Marble, Egyptian | 2,668 | 166·7500 | 1·54976 | 10·3628 |
| Slate | 2,672 | 167·0000 | 1·54629 | 10·3473 |
| Coral | 2,680 | 167·5000 | 1·55092 | 10·3164 |
| Pearl, Oriental | 2,684 | 167·7500 | 1·55324 | 10·3010 |
| Glass, bottle | 2,733 | 170·8125 | 1·58159 | 10·1163 |
| Marble, green Campanian | 2,742 | 171·3750 | 1·58735 | 10·0831 |
| Emerald of Peru | 2,775 | 173·4375 | 1·60590 | 9·3632 |
| Chalk, British | 2.784 | 174·0000 | 1·61111 | 9·9310 |
| Marble, Parian | 2,837 | 177·3125 | 1·64178 | 9·7455 |
| Basalt, Giants' Causeway | 2,864 | 179·0000 | 1·65740 | 9·6536 |
| Glass, white | 2,892 | 180·7500 | 1·67361 | 9·5601 |
| Limestone | 2,950 | 184·3750 | 1·70717 | 9·3721 |
| Asbestos | 2,996 | 187·2500 | 1·73379 | 9·2283 |
| Hornblende | 3,000 | 187·5000 | 1·73611 | 9·2160 |
| White Lead | 3,160 | 197·5000 | 1·82870 | 8·7493 |
| Glass, British flint | 3,329 | 208·0625 | 1·92650 | 8·3052 |
| Diamond, average | 3,536 | 221·0000 | 2·04629 | 7·8190 |
| Beryl, Oriental | 3,549 | 221·3125 | 2·05381 | 7·7903 |

TABLE 87.—WEIGHT AND VOLUME OF BODIES (*continued*).

| BODIES. | Weight of One Cubic Foot. | | Weight of One Cubic Inch. | Cubic Inches in One Pound. |
|---|---|---|---|---|
| | Oz. | Lb. | Oz. | Cub. In. |
| EARTH, STONES, &c. (*continued*). | | | | |
| Garnet, common . . | 3,576 | 223·5000 | 2·06944 | 7·7315 |
| Topaz, average . . | 3,800 | 237·5000 | 2·19907 | 7·2800 |
| Sapphire, Oriental . . | 3,994 | 243·3750 | 2·25347 | 7·1001 |
| Garnet, precious . . | 4,230 | 264·3750 | 2·44791 | 6·5361 |
| Ruby, Oriental . . | 4,283 | 267·6875 | 2·47858 | 6·4590 |
| Jargon of Ceylon . | 4,416 | 276·0000 | 2·55555 | 6·2608 |
| Spar, heavy . . . | 4,430 | 276·8750 | 2·56365 | 6·2410 |
| Loadstone . . . . | 4,930 | 308·1250 | 2·85300 | 5·6081 |
| The earth (mean of the globe) . . | 5,210 | 325·6250 | 3·01504 | 5·3067 |
| RESINS, GUMS, &c. | | | | |
| Gunpowder, loose heap | 836 | 52·2500 | 0·48379 | 33·0717 |
| Living men . . . | 891 | 55·6875 | 0·51562 | 31·0303 |
| Wax . . . . . . | 897 | 56·0625 | 0·51909 | 30·8227 |
| Ice . . . . . . . | 930 | 58·1250 | 0·53819 | 29·7293 |
| Gunp'wder, close shaken | 937 | 58·5625 | 0·54224 | 29·5069 |
| Tallow . . . . . | 942 | 58·8750 | 0·54513 | 29·3503 |
| Butter . . . . | 942 | 58·8750 | 0·54513 | 29·2993 |
| Beeswax . . . . | 956 | 59·7500 | 0·55324 | 28·9205 |
| Sodium . . . . | 972 | 60·7500 | 0·56250 | 28·4444 |
| Camphor . . . . | 989 | 61·8125 | 0·56655 | 27·9555 |
| Rosin . . . . . | 1,100 | 68·7000 | 0·63657 | 25·0909 |
| Pitch . . . . . | 1,150 | 71·8750 | 0·66550 | 24·0417 |
| Opium . . . . | 1,337 | 83·5625 | 0·77372 | 20·6791 |
| Gum Arabic . . . . | 1,452 | 90·7500 | 0·84027 | 19·0413 |
| Honey . . . . | 1,456 | 91·0000 | 0·84259 | 18·9890 |
| Bone, of an ox . . | 1,659 | 103·6875 | 0·96006 | 16·6654 |
| „ dry . . . . | 1,660 | 103·7500 | 0·96064 | 16·6554 |
| Phosphorus . . . | 1,714 | 107·1250 | 0·99184 | 16·1307 |
| Alum . . . . . | 1,714 | 107·1250 | 0·99184 | 16·1307 |
| Gunpowder, solid . . | 1,745 | 109·0625 | 1·00983 | 15·8441 |
| Nitre (saltpetre) . | 1,900 | 118·7500 | 1·09953 | 14·5515 |
| Ivory . . . . . | 1,917 | 119·8125 | 1·10937 | 14·4422 |
| WOODS. | | | | |
| Cork . . . . . | 240 | 15·0000 | 0·13888 | 115·2000 |

TABLE 87.—WEIGHT AND VOLUME OF BODIES (*continued*).

| Bodies. | Weight of One Cubic Foot. | | Weight of One Cubic Inch. | Cubic Inches in One Pound. |
|---|---|---|---|---|
| | Oz. | Lb. | Oz. | Cub. In. |
| WOODS (*continued*). | | | | |
| Poplar | 383 | 23·9375 | 0·22164 | 71·7650 |
| Larch | 544 | 34·0000 | 0·31481 | 50·8235 |
| Fir, North of England | 556 | 34·7500 | 0·32175 | 49·7266 |
| Mahogany, Honduras | 560 | 35·0000 | 0·32407 | 49·3714 |
| Cedar, American | 561 | 35·0625 | 0·32465 | 49·2833 |
| Poon | 579 | 36·1875 | 0·33506 | 47·7512 |
| Willow | 585 | 36·5625 | 0·35858 | 47·2615 |
| Cedar | 596 | 37·2500 | 0·34490 | 46·3892 |
| Cypress | 598 | 37·3750 | 0·34664 | 46·2341 |
| Elm | 600 | 37·5000 | 0·34722 | 46·0800 |
| Pitch-pine | 660 | 41·2500 | 0·38194 | 41·8909 |
| Pear-tree | 661 | 41·3125 | 0·38252 | 41·8275 |
| Walnut | 681 | 42·5625 | 0·39467 | 40·5991 |
| Fir, Mar Forest | 694 | 43·3750 | 0·40162 | 39·8386 |
| Elder-tree | 695 | 43·4375 | 0·40219 | 39·7812 |
| Orange-tree | 705 | 44·0625 | 0·40798 | 39·2170 |
| Cherry-tree | 715 | 44·6875 | 0·41377 | 38·6685 |
| Teak | 745 | 46·5625 | 0·43113 | 37·1114 |
| Fir, Riga | 750 | 46·8750 | 0·43402 | 36·8640 |
| Maple | 755 | 47·1857 | 0·43692 | 36·6198 |
| Oak, Dantzic | 760 | 47·5000 | 0·43981 | 36·3789 |
| Yew, Dutch | 788 | 49·2500 | 0·45590 | 35·0862 |
| Apple-tree | 793 | 49·5625 | 0·45891 | 34·8656 |
| Yew, Spanish | 807 | 50·4375 | 0·46701 | 34·2602 |
| Ash | 845 | 52·8125 | 0·48900 | 32·7195 |
| Beech | 852 | 53·2500 | 0·49305 | 32·4507 |
| Oak, Canadian | 872 | 54·5000 | 0·50694 | 31·7064 |
| Logwood | 913 | 57·0625 | 0·53125 | 30·2825 |
| Oak, English | 970 | 60·6250 | 0·56134 | 28·5030 |
| Box, French | 1,030 | 64·3750 | 0·59606 | 26·8427 |
| Brazil-wood, red | 1,031 | 64·3125 | 0·59664 | 26·8680 |
| Mahogany, Spanish | 1,063 | 66·4250 | 0·61516 | 26·0143 |
| Oak, English, 60 yrs old | 1,170 | 73·1250 | 0·67708 | 23·6307 |
| Ebony, American | 1,331 | 83·1875 | 0·77025 | 20·7723 |
| Lignum-vitæ | 1,333 | 83·3125 | 0·77141 | 20·7411 |
| LIQUIDS. | | | | |
| Ether, sulphuric | 720 | 45·0000 | 0·41666 | 38·4000 |

TABLE 87.—WEIGHT AND VOLUME OF BODIES (*continued*).

| BODIES. | Weight of One Cubic Foot. | | Weight of One Cubic Inch. | Cubic Inches in One Pound. |
|---|---|---|---|---|
| | Oz. | Lb. | Oz. | Cub. In. |
| LIQUIDS (*continued*). | | | | |
| Alcohol, absolute | 796 | 49·7500 | 0·46064 | 34·7487 |
| Brandy | 837 | 52·3125 | 0·48437 | 33·0322 |
| Bitumen, liquid | 848 | 53·0000 | 0·49074 | 32·6037 |
| Turpentine, oil of | 870 | 54·3750 | 0·50347 | 31·9632 |
| Ether, muriatic | 874 | 54·6250 | 0·50578 | 31·6338 |
| Olive oil | 915 | 57·1875 | 0·52951 | 30·2163 |
| Moselle wine | 916 | 57·2500 | 0·53009 | 30·1834 |
| Whale oil | 923 | 57·6875 | 0·53414 | 29·9544 |
| Proof spirit | 930 | 58·1250 | 0·53819 | 29·7290 |
| Linseed oil | 940 | 58·7500 | 0·54398 | 29·4127 |
| Castor oil | 970 | 60·6250 | 0·56134 | 28·5030 |
| Wine, red port | 990 | 61·8750 | 0·57291 | 27·9272 |
| " of Burgundy | 991 | 61·9375 | 0·57349 | 27·8990 |
| " of Bordeaux | 994 | 62·1250 | 0·57523 | 27·8148 |
| " white Champagne | 997 | 62·3125 | 0·57696 | 27·7311 |
| Water, distilled | 1,000 | 62·5000 | 0·57870 | 27·6480 |
| Tar | 1,015 | 63·4375 | 0·58738 | 27·2396 |
| Vinegar | 1,026 | 64·1250 | 0·59375 | 26·9473 |
| Sea-water | 1,028 | 64·2500 | 0·59490 | 26·8949 |
| Milk | 1,030 | 64·3750 | 0·59606 | 26·8427 |
| Ale (average) | 1,035 | 64·6875 | 0·59895 | 26·7130 |
| Blood, human | 1,045 | 65·3125 | 0·60474 | 26·4574 |
| Muriatic acid of commerce | 1,218 | 76·1250 | 0·70486 | 22·6995 |
| Aqua regia | 1,234 | 77·1250 | 0·71412 | 22·4051 |
| Water of Dead Sea | 1,240 | 77·5000 | 0·71759 | 22·2580 |
| Nitrous acid | 1,452 | 90·7500 | 0·84024 | 19·0082 |
| Nitric acid, or aquafortis | 1,500 | 93·7500 | 0·86805 | 18·4000 |
| Boracic acid | 1,830 | 114·3750 | 1·05902 | 15·1081 |
| Sulphuric acid | 1,848 | 128·0000 | 1·06944 | 13·5000 |
| Quicksilver | (See Metals.) | | | |

## Table 88.—Specific Gravities of Bodies.

*(Adopted by the Standards Department of the Board of Trade.)*

| —— | Specific Gravity. |
|---|---|
| Agate | 2·6 |
| Aluminium (rolled) | 2·67 |
| „ bronze, copper 9, aluminium 1 | 8·0 |
| Antimony | 6·72 |
| Arsenic | 5·67 |
| Barium | 4·0 |
| Beech | 0·8 |
| Bismuth | 9·82 |
| Bone | 1·8 to 2·0 |
| Boron | 2·69 |
| Brass | 8·0 |
| Brick, ordinary | 2·17 |
| Bromine | 2·966 |
| Bronze, copper 86·3, zinc 4·0, tin 9·7 | 8·45 |
| Bronze, copper 32, zinc 2, tin 5 (Baily's) | 8·4 |
| Bronze coins, copper 95, zinc 1, tin 4 | 8·66 |
| Calcium | 1·58 |
| Carbonic acid gas | 1·529 |
| Chalk | 2·1 |
| Cobalt | 7·81 |
| Copper (rolled) | 8·94 |
| Cork | 0·24 |
| Ebony | 1·18 |
| Ether, $C_8H_{10}O_2$ | 0·73 |
| Glass, ordinary crown | 2·45 |
| „ French | 2·65 |
| „ flint | 3·59 |
| „ crystal | 3·33 |
| Glycerine | 1·27 |
| Gold | 19·32 |
| „ alloy (18 carat) | 14·88 |
| „ „ gold 983, copper 17 | 18·92 |
| „ „ 11 „ 1 | 17·49 |
| „ „ 9 „ 1 | 17·17 |
| Granite | 2·64 to 2·76 |
| Hydrogen | 0·06926 |
| Iodine | 4·95 |
| Iridium | 22·38 |
| Iron: | |
| „ wrought | 7·79 |

TABLE 88.—SPECIFIC GRAVITIES OF BODIES (*continued*).

| — | Specific Gravity. |
|---|---|
| Iron, cast | 7·20 |
| Lead | 11·35 |
| Magnesium | 1·74 |
| Mahogany | 0·56 |
| Manganese | 8·01 |
| Marble | 2·52 to 2·84 |
| Mercury | 13·59593 |
| Nickel (rolled) | 8·67 |
| Nitric acid (fuming) | 1·451 |
| Nitrogen | 0·97137 |
| Oak | 0·93 |
| Oil, olive | 0·91 |
| ,, sperm | 0·93 |
| ,, colza | 0·91 |
| Osmium | 21·40 |
| Oxygen | 1·10563 |
| Palladium (rolled) | 11·78 |
| Palladium alloy, Matthey's Standard, silver 60°/$_{\circ}$, palladium, 40°/$_{\circ}$ | 11·00 |
| Petroleum | 0·84 |
| Pine wood | 0·56 |
| Phosphorus | 1·77 |
| Porcelain | 2·5 |
| Platinum | 21·45 |
| ,, alloy, platinum 90, iridium 10 | 21·57 |
| ,, ,, ,, 85, ,, 15 | 21·58 |
| ,, ,, ,, 2, ,, 1 | 21·62 |
| ,, ,, ,, 5, ,, 95 | 22·35 |
| Potassium | 0·86 |
| Quartz | 2·65122 |
| Rhodium | 12·1 |
| Rock crystal, *see* Quartz. | |
| Ruthenium | 12·29 |
| Selenium | 4·30 |
| Silver | 10·51 |
| ,, alloy, silver 37, copper 3 | 10·38 |
| ,, ,, 9 ,, 1 | 10·31 |
| ,, ,, 835 ,, 165 | 10·20 |
| ,, ,, 80 ,, 20 | 10·06 |
| ,, ,, 60 ,, 40 | 9·80 |
| ,, ,, $13\frac{1}{4}$ ,, $2\frac{3}{4}$ | 10·17 |
| Slate | 2·11 |
| Sodium | 0·97 |

TABLE 88.—SPECIFIC GRAVITIES OF BODIES (*continued*).

| | Specific Gravity. |
|---|---|
| Steel (Whitworth's compressed) | 7·796 |
| Strontium | 2·54 |
| Sulphur | 2·0 |
| Sulphuric acid | 1·848 |
| Teak | 0·86 |
| Thallium | 11·88 |
| Tin | 7·29 |
| Water { pure at 0°C. / $D_{4°} = 1$ } | 0·9998635 |
| Wax | 0·95 |
| Zinc, sheet | 7·19 |

## MANUFACTURED METALS.

### Tables of Weights of Manufactured Metals.

The following tables are for the most part calculated for the ordinary dimensions manufactured by the trades.

The units of specific gravity and weights adopted in the calculations of these tables, excepting where otherwise stated, are as follows:—

| METALS. | Specific Gravity. | Weight of One Cubic Foot. | Weight of One Cubic Inch. |
|---|---|---|---|
| | Water = 1·000. | Pounds. | Pound. |
| Wrought Iron | 7·698 | 480 | ·2778 |
| Steel | 7·858 | 490 | ·2836 |
| Cast Iron | 7·217 | 450 | ·2604 |
| Lead | 11·355 | 708 | ·4097 |
| Copper | 8·8917 | 554·4 | ·3208 |
| Brass (70 copper, 30 zinc) | 8·558 | 533·6 | ·3088 |
| " (2 " 1 " ) | 8·508 | 530·5 | ·3070 |

The values above given for copper and brass are the results of very careful investigations made by the Broughton Copper Company.

The weights of other metals may be calculated by means of suitable multipliers from the weights of any given metal. Taking the weights of wrought-iron, copper, and the brasses successively as 1, the respective multipliers for the weights of the other metals are as follows :—

| Metal. | Wrought Iron = 1. | Copper = 1. | Brass (70 C. and 30 Z.) = 1. |
|---|---|---|---|
| Wrought Iron . . . . | 1·000 | ·8658 | ·8995 |
| Steel . . . . . . | 1·0208 | ·8837 | ·9182 |
| Cast Iron . . . . | ·9375 | ·8117 | ·8433 |
| Lead . . . . . . | 1·4750 | 1·2771 | 1·3269 |
| Copper . . . . . . | 1·1550 | 1·0000 | 1·0388 |
| Brass (70 copper, 30 zinc) . | 1·1117 | ·9625 | 1·0000 |
| ,, (2 ,, 1 ,, ) . | 1·1052 | ·9568 | ·9941 |

### Bars or Rods, and Wire.

Bars or rods are rolled to dimensions in inches and fractions of an inch, as exhibited in following Tables. Wire generally is rolled to the Imperial Gauge.

### Tubes.

Boiler tubes, of iron, steel, or brass, are manufactured to given external diameters. Iron or steel tubes for gas, steam, or water, are manufactured to given internal diameters. Copper tubes also are ordinarily manufactured to internal diameters. The thicknesses of tubes are, for the most part, regulated on the basis of the Imperial Wire-Gauge. But the old Birmingham Wire-Gauge is also, to some extent, followed.

### Joists and Girders.

The dimensions, weights, and calculated loads of joists and girders, of iron and steel are given in following Tables. The calculated strengths have been verified by numerous actual tests. The factor of safety, 4, applies to the uniformly loaded joists and girders of Messrs. Measures Brothers & Co.; the factor, 3, is applied for the distributed loads of the steel joists and girders of Messrs. Dorman, Long & Co.; and the breaking weight, applied at the centre, is given with the co-efficients of strength in the joists of the Butterley Company.

Joists fail under loads by the breaking of the flange in compression; never by tensile stress.

The normal length of joists is 30 feet.

TABLE 89.—METALS: WEIGHTS FOR VARIOUS DIMENSIONS.

| Metal. | Specific Weight. | Weight of One Cubic Foot. | Weight of One Square Foot. 1 Inch Thick. | 1/8th Inch Thick. | 1/10th Inch Thick. | Weight of One Lineal Ft. 1 In. Sq. | Weight of One Cubic Inch. |
|---|---|---|---|---|---|---|---|
| | Wro'ght Iron = 1. | Lb. | Lb. | Lb. | Lb. | Lb. | Lb. |
| Aluminium, wrought | ·348 | 167 | 13·92 | 1·74 | 1·39 | 1·160 | ·097 |
| „ cast . . | ·333 | 160 | 13·33 | 1·67 | 1·33 | 1·111 | ·092 |
| Antimony . . | ·879 | 418 | 34·83 | 4·35 | 3·48 | 2·902 | ·242 |
| Bismuth . . . | 1·285 | 617 | 51·42 | 6·42 | 5·14 | 4·283 | ·357 |
| Brass, cast . . | 1·052 | 505 | 42·08 | 5·26 | 4·21 | 3·507 | ·292 |
| „ sheet . . | 1·098 | 527 | 43·92 | 5·49 | 4·39 | 3·652 | ·304 |
| „ yellow . . | 1·079 | 518 | 43·17 | 5·40 | 4·32 | 3·597 | ·298 |
| „ Muntz metal. | 1·062 | 511 | 42·58 | 5·32 | 4·26 | 3·549 | ·296 |
| „ wire . . | 1·110 | 533 | 44·42 | 5·55 | 4·44 | 3·701 | ·308 |
| Bronze, gun-metal . | 1·106 | 531 | 44·25 | 5·54 | 4·43 | 3·688 | ·307 |
| „ mill bearings . | 1·133 | 544 | 45·33 | 5·66 | 4·53 | 3·780 | ·315 |
| „ small bells . | 1·004 | 482 | 40·17 | 5·04 | 4·02 | 3·347 | ·279 |
| „ speculum metal | ·969 | 465 | 38·75 | 4·84 | 3·88 | 3·299 | ·269 |
| Copper, sheet . . | 1·114 | 549 | 45·75 | 5·72 | 4·58 | 3·813 | ·318 |
| „ hammered . | 1·158 | 556 | 46·33 | 5·79 | 4·63 | 3·861 | ·322 |
| „ wire . . | 1·154 | 554 | 46·17 | 5·77 | 4·62 | 3·778 | ·315 |
| Gold . . . . | 2·500 | 1200 | 100·00 | 12·50 | 10·00 | 8·333 | ·694 |
| Iron, cast . . . | ·937 | 450 | 37·50 | 4·69 | 3·75 | 3·125 | ·260 |
| „ wrought . . | 1·000 | 480 | 40·00 | 5·00 | 4·00 | 3·333 | ·278 |
| Lead, sheet . . | 1·483 | 712 | 59·33 | 7·41 | 5·93 | 4·944 | ·412 |
| Manganese . . | 1·040 | 499 | 41·58 | 5·20 | 4·16 | 3·465 | ·289 |
| Mercury . . . | 1·769 | 849 | 70·75 | 8·84 | 7·07 | 5·896 | ·491 |
| Nickel, hammered . | 1·127 | 541 | 45·08 | 5·64 | 4·51 | 3·757 | ·313 |
| „ cast . . | 1·075 | 516 | 43·00 | 5·37 | 4·30 | 3·583 | ·299 |
| Platinum . . | 2·796 | 1342 | 111·83 | 13·97 | 11·18 | 9·320 | ·777 |
| Silver . . . | 1·365 | 655 | 54·58 | 6·82 | 5·46 | 4·549 | ·379 |
| Steel . . . . | 1·020 | 490 | 40·83 | 5·12 | 4·10 | 3·403 | ·284 |
| Tin . . . . . | ·962 | 462 | 38·50 | 4·81 | 3·85 | 3·208 | ·268 |
| Zinc, sheet . . . | ·935 | 449 | 37·42 | 4·67 | 3·74 | 3·118 | ·260 |
| „ cast . . . | ·892 | 428 | 35·67 | 4·46 | 3·57 | 2·972 | ·248 |

## Table 90.—Weights of Flat Bar Iron

Length 1 Foot.

| Thickness. | Width in Inches. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | $\frac{1}{2}$ | $\frac{5}{8}$ | $\frac{3}{4}$ | $\frac{7}{8}$ | 1 | $1\frac{1}{8}$ | $1\frac{1}{4}$ | $1\frac{3}{8}$ | $1\frac{1}{2}$ |
| Inch. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. |
| $\frac{1}{8}$ | ·208 | ·260 | ·312 | ·365 | ·417 | ·469 | ·521 | ·573 | ·625 |
| $\frac{3}{16}$ | ·312 | ·391 | ·469 | ·547 | ·625 | ·703 | ·781 | ·859 | ·937 |
| $\frac{1}{4}$ | ·417 | ·521 | ·625 | ·729 | ·833 | ·938 | 1·04 | 1·15 | 1·25 |
| $\frac{5}{16}$ | ·521 | ·651 | ·781 | ·911 | 1·04 | 1·17 | 1·30 | 1·43 | 1·56 |
| $\frac{3}{8}$ | ·625 | ·781 | ·937 | 1·09 | 1·25 | 1·41 | 1·56 | 1·72 | 1·88 |
| $\frac{7}{16}$ | ·729 | ·911 | 1·09 | 1·28 | 1·46 | 1·64 | 1·82 | 2·01 | 2·19 |
| $\frac{1}{2}$ | ·833 | 1·04 | 1·25 | 1·46 | 1·67 | 1·88 | 2·08 | 2·29 | 2·50 |
| $\frac{9}{16}$ | ·937 | 1·17 | 1·41 | 1·64 | 1·88 | 2·11 | 2·34 | 2·58 | 2·81 |
| $\frac{5}{8}$ | 1·04 | 1·30 | 1·56 | 1·82 | 2·08 | 2·34 | 2·60 | 2·86 | 3·13 |
| $\frac{11}{16}$ | 1·15 | 1·43 | 1·72 | 2·01 | 2·29 | 2·58 | 2·86 | 3·15 | 3·44 |
| $\frac{3}{4}$ | 1·25 | 1·56 | 1·87 | 2·19 | 2·50 | 2·81 | 3·13 | 3·44 | 3·75 |
| $\frac{13}{16}$ | 1·35 | 1·69 | 2·03 | 2·37 | 2·71 | 3·05 | 3·39 | 3·72 | 4·06 |
| $\frac{7}{8}$ | 1·46 | 1·82 | 2·19 | 2·55 | 2·92 | 3·28 | 3·65 | 4·01 | 4·38 |
| $\frac{15}{16}$ | 1·56 | 1·95 | 2·34 | 2·73 | 3·13 | 3·52 | 3·91 | 4·30 | 4·69 |
| 1 | 1·67 | 2·08 | 2·50 | 2·92 | 3·33 | 3·75 | 4·17 | 4·58 | 5·00 |

| Thickness. | Width in Inches. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $1\frac{5}{8}$ | $1\frac{3}{4}$ | $1\frac{7}{8}$ | 2 | $2\frac{1}{8}$ | $2\frac{1}{4}$ | $2\frac{3}{8}$ | $2\frac{1}{2}$ | $2\frac{5}{8}$ | $2\frac{3}{4}$ |
| Inch. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. |
| $\frac{1}{8}$ | ·677 | ·729 | ·781 | ·833 | ... | ... | ... | ... | ... | ... |
| $\frac{3}{16}$ | 1·02 | 1·09 | 1·17 | 1·25 | 1·33 | 1·41 | 1·48 | 1·56 | 1·64 | 1·72 |
| $\frac{1}{4}$ | 1·35 | 1·46 | 1·56 | 1·67 | 1·77 | 1·88 | 1·98 | 2·08 | 2·19 | 2·29 |
| $\frac{5}{16}$ | 1·69 | 1·82 | 1·95 | 2·08 | 2·21 | 2·34 | 2·47 | 2·60 | 2·73 | 2·86 |
| $\frac{3}{8}$ | 2·03 | 2·19 | 2·34 | 2·50 | 2·66 | 2·81 | 2·97 | 3·13 | 3·28 | 3·44 |
| $\frac{7}{16}$ | 2·37 | 2·55 | 2·73 | 2·92 | 3·10 | 3·28 | 3·46 | 3·65 | 3·83 | 4·01 |
| $\frac{1}{2}$ | 2·71 | 2·92 | 3·13 | 3·33 | 3·54 | 3·75 | 3·96 | 4·17 | 4·38 | 4·58 |
| $\frac{9}{16}$ | 3·05 | 3·28 | 3·52 | 3·75 | 3·98 | 4·22 | 4·45 | 4·69 | 4·92 | 5·16 |
| $\frac{5}{8}$ | 3·39 | 3·65 | 3·91 | 4·17 | 4·43 | 4·69 | 4·95 | 5·21 | 5·47 | 5·73 |
| $\frac{11}{16}$ | 3·72 | 4·01 | 4·30 | 4·58 | 4·87 | 5·16 | 5·44 | 5·73 | 6·02 | 6·30 |
| $\frac{3}{4}$ | 4·06 | 4·38 | 4·69 | 5·00 | 5·31 | 5·63 | 5·94 | 6·25 | 6·56 | 6·88 |
| $\frac{13}{16}$ | 4·40 | 4·74 | 5·08 | 5·42 | 5·76 | 6·09 | 6·43 | 6·77 | 7·11 | 7·45 |
| $\frac{7}{8}$ | 4·74 | 5·10 | 5·47 | 5·83 | 6·20 | 6·56 | 6·93 | 7·29 | 7·66 | 8·02 |
| $\frac{15}{16}$ | 5·08 | 5·47 | 5·86 | 6·25 | 6·64 | 7·03 | 7·42 | 7·81 | 8·20 | 8·59 |
| 1 | 5·42 | 5·83 | 6·25 | 6·67 | 7·08 | 7·50 | 7·92 | 8·33 | 8·75 | 9·17 |

TABLE 90.—WEIGHTS OF FLAT BAR IRON (*continued*).

| Thickness. | Width in Inches. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $2\frac{7}{8}$ | 3 | $3\frac{1}{4}$ | $3\frac{1}{2}$ | $3\frac{3}{4}$ | 4 | $4\frac{1}{4}$ | $4\frac{1}{2}$ | $4\frac{3}{4}$ | 5 |
| Inch. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. |
| $\frac{3}{16}$ | 1·80 | 1·88 | 2·03 | ... | ... | ... | ... | ... | ... | ... |
| $\frac{1}{4}$ | 2·40 | 2·50 | 2·71 | 2·92 | 3·13 | 3·33 | 3·54 | 3·75 | 3·96 | 4·17 |
| $\frac{5}{16}$ | 3·00 | 3·13 | 3·39 | 3·65 | 3·91 | 4·17 | 4·43 | 4·69 | 4·95 | 5·21 |
| $\frac{3}{8}$ | 3·59 | 3·75 | 4·06 | 4·38 | 4·69 | 5·00 | 5·31 | 5·63 | 5·94 | 6·25 |
| $\frac{7}{16}$ | 4·19 | 4·38 | 4·74 | 5·10 | 5·47 | 5·83 | 6·20 | 6·56 | 6·93 | 7·29 |
| $\frac{1}{2}$ | 4·79 | 5·00 | 5·42 | 5·83 | 6·25 | 6·67 | 7·08 | 7·50 | 7·92 | 8·33 |
| $\frac{9}{16}$ | 5·39 | 5·63 | 6·09 | 6·56 | 7·03 | 7·50 | 7·97 | 8·44 | 8·91 | 9·38 |
| $\frac{5}{8}$ | 6·00 | 6·25 | 6·77 | 7·29 | 7·81 | 8·33 | 8·85 | 9·38 | 9·90 | 10·4 |
| $\frac{11}{16}$ | 6·59 | 6·88 | 7·45 | 8·02 | 8·59 | 9·17 | 9·74 | 10·3 | 10·9 | 11·5 |
| $\frac{3}{4}$ | 7·19 | 7·50 | 8·13 | 8·75 | 9·38 | 10·0 | 10·6 | 11·3 | 11·9 | 12·5 |
| $\frac{13}{16}$ | 7·79 | 8·13 | 8·80 | 9·48 | 10·2 | 10·8 | 11·5 | 12·2 | 12·9 | 13·5 |
| $\frac{7}{8}$ | 8·39 | 8·75 | 9·48 | 10·2 | 10·9 | 11·7 | 12·4 | 13·1 | 13·9 | 14·6 |
| $\frac{15}{16}$ | 8·98 | 9·38 | 10·2 | 10·9 | 11·7 | 12·5 | 13·3 | 14·1 | 14·8 | 15·6 |
| 1 | 9·58 | 10·0 | 10·8 | 11·7 | 12·5 | 13·3 | 14·2 | 15·0 | 15·8 | 16·7 |

| Thickness. | Width in Inches. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | $5\frac{1}{2}$ | 6 | $6\frac{1}{2}$ | 7 | 8 | 9 | 10 | 11 | 12 |
| Inch. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. |
| $\frac{1}{4}$ | 4·58 | 5·00 | 5·42 | 5·83 | 6·67 | 7·50 | 8·33 | 9·17 | 10·0 |
| $\frac{5}{16}$ | 5·73 | 6·25 | 6·77 | 7·29 | 8·33 | 9·38 | 10·4 | 11·5 | 12·5 |
| $\frac{3}{8}$ | 6·88 | 7·50 | 8·13 | 8·75 | 10·0 | 11·3 | 12·5 | 13·8 | 15·0 |
| $\frac{7}{16}$ | 8·02 | 8·75 | 9·47 | 10·2 | 11·7 | 13·1 | 14·6 | 16·0 | 17·5 |
| $\frac{1}{2}$ | 9·17 | 10·0 | 10·8 | 11·7 | 13·3 | 15·0 | 16·7 | 18·3 | 20·0 |
| $\frac{9}{16}$ | 10·3 | 11·3 | 12·2 | 13·1 | 15·0 | 16·9 | 18·8 | 20·6 | 22·5 |
| $\frac{5}{8}$ | 11·5 | 12·5 | 13·5 | 14·6 | 16·7 | 18·8 | 20·8 | 22·9 | 25·0 |
| $\frac{11}{16}$ | 12·6 | 13·8 | 14·9 | 16·0 | 18·3 | 20·6 | 22·9 | 25·2 | 27·5 |
| $\frac{3}{4}$ | 13·8 | 15·0 | 16·3 | 17·5 | 20·0 | 22·5 | 25·0 | 27·5 | 30·0 |
| $\frac{13}{16}$ | 14·9 | 16·3 | 17·6 | 19·0 | 21·7 | 24·4 | 27·1 | 29·8 | 32·5 |
| $\frac{7}{8}$ | 16·0 | 17·5 | 19·0 | 20·4 | 23·3 | 26·3 | 29·2 | 32·1 | 35·0 |
| $\frac{15}{16}$ | 17·2 | 18·8 | 20·3 | 21·9 | 25·0 | 28·1 | 31·3 | 34·4 | 37·5 |
| 1 | 18·3 | 20·0 | 21·7 | 23·3 | 26·7 | 30·0 | 33·3 | 36·7 | 40·0 |

## TABLE 91.—WEIGHTS OF ROUND IRON.

Length, 1 Foot.

| Diam. | Weight. | Diam. | Weight. | Diam. | Weight. | Diam. | Weight. |
|---|---|---|---|---|---|---|---|
| Inches. | Lbs. | Inches. | Lbs. | Inches. | Lbs. | Inches. | Cwts. |
| $\frac{1}{8}$ | ·041 | 1 | 2·62 | $2\frac{3}{8}$ | 14·8 | 8 | 1·496 |
| $\frac{5}{32}$ | ·064 | $1\frac{1}{32}$ | 2·78 | $2\frac{7}{16}$ | 15·6 | $8\frac{1}{2}$ | 1·689 |
| $\frac{3}{16}$ | ·092 | $1\frac{1}{16}$ | 2·96 | $2\frac{1}{2}$ | 16·4 | 9 | 1·893 |
| $\frac{7}{32}$ | ·125 | $1\frac{3}{32}$ | 3·14 | $2\frac{5}{8}$ | 18·0 | $9\frac{1}{2}$ | 2·110 |
| $\frac{1}{4}$ | ·164 | $1\frac{1}{8}$ | 3·31 | $2\frac{3}{4}$ | 19·8 | 10 | 2·338 |
| $\frac{9}{32}$ | ·207 | $1\frac{5}{32}$ | 3·50 | $2\frac{7}{8}$ | 21·6 | $10\frac{1}{2}$ | 2·577 |
| $\frac{5}{16}$ | ·256 | $1\frac{3}{16}$ | 3·69 | 3 | 23·6 | 11 | 2·828 |
| $\frac{11}{32}$ | ·310 | $1\frac{7}{32}$ | 3·90 | $3\frac{1}{8}$ | 25·6 | $11\frac{1}{2}$ | 3·088 |
| $\frac{3}{8}$ | ·368 | $1\frac{1}{4}$ | 4·09 | $3\frac{1}{4}$ | 27·7 | 12 | 3·366 |
| $\frac{13}{32}$ | ·432 | $1\frac{9}{32}$ | 4·29 | $3\frac{3}{8}$ | 29·8 | $12\frac{1}{2}$ | 3·656 |
| $\frac{7}{16}$ | ·501 | $1\frac{5}{16}$ | 4·51 | $3\frac{1}{2}$ | 32·1 | 13 | 3·950 |
| $\frac{15}{32}$ | ·575 | $1\frac{11}{32}$ | 4·70 | $3\frac{5}{8}$ | 34·4 | $13\frac{1}{2}$ | 4·260 |
| $\frac{1}{2}$ | ·654 | $1\frac{3}{8}$ | 4·95 | $3\frac{3}{4}$ | 36·8 | 14 | 4·581 |
| $\frac{17}{32}$ | ·740 | $1\frac{7}{16}$ | 5·08 | $3\frac{7}{8}$ | 39·3 | $14\frac{1}{2}$ | 4·915 |
| $\frac{9}{16}$ | ·828 | $1\frac{1}{2}$ | 5·89 | 4 | 41·9 | 15 | 5·259 |
| $\frac{19}{32}$ | ·922 | $1\frac{9}{16}$ | 6·29 | $4\frac{1}{4}$ | 47·3 | $15\frac{1}{2}$ | 5·616 |
| $\frac{5}{8}$ | 1·02 | $1\frac{5}{8}$ | 6·91 | $4\frac{1}{2}$ | 53·0 | 16 | 5·984 |
| $\frac{21}{32}$ | 1·13 | $1\frac{11}{16}$ | 7·46 | $4\frac{3}{4}$ | 59·1 | $16\frac{1}{2}$ | 6·364 |
| $\frac{11}{16}$ | 1·24 | $1\frac{3}{4}$ | 8·02 | 5 | 65·5 | 17 | 6·755 |
| $\frac{23}{32}$ | 1·27 | $1\frac{13}{16}$ | 8·60 | $5\frac{1}{4}$ | 72·2 | $17\frac{1}{2}$ | 7·159 |
| $\frac{3}{4}$ | 1·47 | $1\frac{7}{8}$ | 9·20 | $5\frac{1}{2}$ | 79·2 | 18 | 7·573 |
| $\frac{25}{32}$ | 1·60 | $1\frac{15}{16}$ | 9·83 | $5\frac{3}{4}$ | 86·6 | 19 | 8·438 |
| $\frac{13}{16}$ | 1·73 | 2 | 10·5 | 6 | 94·2 | 20 | 9·350 |
| $\frac{27}{32}$ | 1·86 | $2\frac{1}{16}$ | 11·1 | | | 21 | 10·31 |
| $\frac{7}{8}$ | 2·00 | $2\frac{1}{8}$ | 11·8 | Inches. | Cwts. | 22 | 11·31 |
| $\frac{29}{32}$ | 2·15 | $2\frac{3}{16}$ | 12·6 | $6\frac{1}{2}$ | ·9876 | 23 | 12·37 |
| $\frac{15}{16}$ | 2·30 | $2\frac{1}{4}$ | 13·3 | 7 | 1·145 | 24 | 13·46 |
| $\frac{31}{32}$ | 2·46 | $2\frac{5}{16}$ | 14·0 | $7\frac{1}{2}$ | 1·315 | | |

## TABLE 92.—WEIGHTS OF SQUARE IRON.

Length, 1 Foot.

| Side of Square. | Weight. | Side of Square. | Weight. | Side of Square. | Weight. | Side of Square. | Weight. |
|---|---|---|---|---|---|---|---|
| Inches. | Lbs. | Inches. | Lbs. | Inches. | Lbs. | Inches. | Lbs. |
| $\frac{1}{8}$ | ·052 | $\frac{11}{16}$ | 1·58 | $1\frac{7}{32}$ | 4·96 | $2\frac{1}{2}$ | 20·8 |
| $\frac{5}{32}$ | ·081 | $\frac{23}{32}$ | 1·72 | $1\frac{1}{4}$ | 5·21 | $2\frac{5}{8}$ | 23·0 |
| $\frac{3}{16}$ | ·117 | $\frac{3}{4}$ | 1·88 | $1\frac{5}{16}$ | 5·74 | $2\frac{3}{4}$ | 25·2 |
| $\frac{7}{32}$ | ·159 | $\frac{25}{32}$ | 2·03 | $1\frac{3}{8}$ | 6·30 | $2\frac{7}{8}$ | 27·6 |
| $\frac{1}{4}$ | ·208 | $\frac{13}{16}$ | 2·20 | $1\frac{7}{16}$ | 6·89 | 3 | 30·0 |
| $\frac{9}{32}$ | ·265 | $\frac{27}{32}$ | 2·40 | $1\frac{1}{2}$ | 7·50 | $3\frac{1}{4}$ | 35·2 |
| $\frac{5}{16}$ | ·326 | $\frac{7}{8}$ | 2·55 | $1\frac{9}{16}$ | 8·14 | $3\frac{1}{2}$ | 40·8 |
| $\frac{11}{32}$ | ·395 | $\frac{29}{32}$ | 2·75 | $1\frac{5}{8}$ | 8·80 | $3\frac{3}{4}$ | 46·9 |
| $\frac{3}{8}$ | ·469 | $\frac{15}{16}$ | 2·93 | $1\frac{11}{16}$ | 9·60 | 4 | 53·3 |
| $\frac{13}{32}$ | ·550 | $\frac{31}{32}$ | 3·12 | $1\frac{3}{4}$ | 10·2 | $4\frac{1}{4}$ | 60·2 |
| $\frac{7}{16}$ | ·638 | 1 | 3·33 | $1\frac{13}{16}$ | 11·0 | $4\frac{1}{2}$ | 67·5 |
| $\frac{15}{32}$ | ·732 | $1\frac{1}{32}$ | 3·54 | $1\frac{7}{8}$ | 11·7 | $4\frac{3}{4}$ | 75·2 |
| $\frac{1}{2}$ | ·833 | $1\frac{1}{16}$ | 3·76 | $1\frac{15}{16}$ | 12·5 | 5 | 83·3 |
| $\frac{17}{32}$ | ·940 | $1\frac{3}{32}$ | 4·03 | 2 | 13·3 | $5\frac{1}{4}$ | 91·9 |
| $\frac{9}{16}$ | 1·06 | $1\frac{1}{8}$ | 4·22 | $2\frac{1}{8}$ | 15·1 | $5\frac{1}{2}$ | 100·8 |
| $\frac{19}{32}$ | 1·17 | $1\frac{5}{32}$ | 4·48 | $2\frac{1}{4}$ | 16·9 | $5\frac{3}{4}$ | 110·2 |
| $\frac{5}{8}$ | 1·30 | $1\frac{3}{16}$ | 4·70 | $2\frac{3}{8}$ | 18·8 | 6 | 120·0 |
| $\frac{21}{32}$ | 1·43 | | | | | | |

### French Bar Iron.

The length of bars varies. In general, it is 4 metres for the larger bars, and 6 metres for the smaller bars ; with a tolerance of $\frac{1}{2}$ metre, more or less. Square iron advances in size by 1 millimetre from 6 to 86 millimetres. Round iron advances by 1 millimetre from 6 to 28 millimetres ; and by 2 millimetres from 28 to 130 millimetres, with a few exceptions. Flat bar iron :—

16, 18, 20, 22, 24, 26, 28, 30, 32, 34, 36 millimetres, by 1 to 3 millimetres thick.

18, 20, 22, 24, 26, 28, 30, 32 millimetres, by 4 to 14 millimetres thick.

34, 40, 42, 46, 48 millimetres, by $1\frac{1}{2}$ to 30 millimetres thick.

48, 50, 52, 54, 58, 60, 62, 64, 66, 68, 70, 72 millimetres, by 2 to 40 millimetres thick.

75 by 2 to 40, 80 by 2 to 45, 85 by 2 to 50, 90 by 2 to 45 95 by 2 to 50, 100 by 2 to 50, 110 by 2 to 40, 115 by 2 to 40

135 by 3 to 45, 140 by 3 to 40, 150 by 3 to 45, 160 by 3 to 45, 165 by 3 to 45, 180 by 3 to 45, 210 by 8 to 45, 250 by 7 to 40, 300 by 8 to 40, 355 by 8 to 40, 400 by 8 to 40, 450 by 8 to 40 millimetres thick.

TABLE 93.—WROUGHT IRON: WEIGHT OF ONE SQUARE FOOT FOR ALL THICKNESSES OF THE IMPERIAL WIRE GAUGE (Standards Department).

Specific Gravity, 7·80.

| I. W. G. Gauge Number. | Thickness. | Weight per Square Foot. | I. W. G. Gauge Number. | Thickness. | Weight per Square Foot. |
|---|---|---|---|---|---|
| No. | Inch. | Pounds. | No. | Inch. | Pounds. |
| 7/0 | ·500 | 20·254 | 23 | ·024 | ·972 |
| 6/0 | ·464 | 18·796 | 24 | ·022 | ·891 |
| 5/0 | ·432 | 17·500 | 25 | ·020 | ·810 |
| 4/0 | ·400 | 16·203 | 26 | ·018 | ·729 |
| 3/0 | ·372 | 15·069 | 27 | ·0164 | ·664 |
| 2/0 | ·348 | 14·097 | 28 | ·0148 | ·600 |
| 0 | ·324 | 13·125 | 29 | ·0136 | ·551 |
| 1 | ·300 | 12·153 | 30 | ·0124 | ·502 |
| 2 | ·276 | 11·180 | 31 | ·0116 | ·470 |
| 3 | ·252 | 10·208 | 32 | ·0108 | ·437 |
| 4 | ·232 | 9·398 | 33 | ·0100 | ·405 |
| 5 | ·212 | 8·588 | 34 | ·0092 | ·373 |
| 6 | ·192 | 7·778 | 35 | ·0084 | ·340 |
| 7 | ·176 | 7·130 | 36 | ·0076 | ·308 |
| 8 | ·160 | 6·481 | 37 | ·0068 | ·275 |
| 9 | ·144 | 5·833 | 38 | ·0060 | ·243 |
| 10 | ·128 | 5·185 | 39 | ·0052 | ·211 |
| 11 | ·116 | 4·699 | 40 | ·0048 | ·194 |
| 12 | ·104 | 4·213 | 41 | ·0044 | ·178 |
| 13 | ·092 | 3·727 | 42 | ·0040 | ·162 |
| 14 | ·080 | 3·241 | 43 | ·0036 | ·146 |
| 15 | ·072 | 2·917 | 44 | ·0032 | ·130 |
| 16 | ·064 | 2·593 | 45 | ·0028 | ·113 |
| 17 | ·056 | 2·268 | 46 | ·0024 | ·097 |
| 18 | ·048 | 1·944 | 47 | ·0020 | ·081 |
| 19 | ·040 | 1·620 | 48 | ·0016 | ·065 |
| 20 | ·036 | 1·458 | 49 | ·0012 | ·049 |
| 21 | ·032 | 1·296 | 50 | ·0010 | ·041 |
| 22 | ·028 | 1·134 | | | |

TABLE 94.—ANGLE IRONS AND TEE IRONS: WEIGHT.
Length, 1 Foot.

| Average Thickness. | Sum of the Width and Depth i Inches. | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 2 | $2\frac{1}{4}$ | $2\frac{1}{2}$ | $2\frac{3}{4}$ | 3 | $3\frac{1}{4}$ | $3\frac{1}{2}$ | $3\frac{3}{4}$ |
| Inch. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. |
| $\frac{1}{8}$ | ·78 | ·88 | ·99 | 1·09 | 1·20 | 1·30 | 1·41 | 1·51 |
| $\frac{3}{16}$ | 1·13 | 1·29 | 1·45 | 1·60 | 1·76 | 1·91 | 2·07 | 2·23 |
| $\frac{1}{4}$ | 1·46 | 1·67 | 1·88 | 2·08 | 2·29 | 2·50 | 2·71 | 2·92 |
| $\frac{5}{16}$ | 1·76 | 2·02 | 2·28 | 2·54 | 2·80 | 3·06 | 3·32 | 3·58 |
| $\frac{3}{8}$ | ... | ... | ... | ... | 3·28 | 3·59 | 3·91 | 4·22 |
| $\frac{7}{16}$ | ... | ... | ... | ... | ... | ... | 4·48 | 4·84 |

| Average Thickness. | Sum of the Width and Depth in Inches. | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 4 | $4\frac{1}{4}$ | $4\frac{1}{2}$ | $4\frac{3}{4}$ | 5 | $5\frac{1}{4}$ | $5\frac{1}{2}$ | $5\frac{3}{4}$ |
| Inch. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. |
| $\frac{3}{16}$ | 2·38 | 2·54 | 2·70 | 2·85 | 3·01 | 3·16 | 3·32 | 3·48 |
| $\frac{1}{4}$ | 3·13 | 3·33 | 3·54 | 3·75 | 3·96 | 4·17 | 4·38 | 4·58 |
| $\frac{5}{16}$ | 3·84 | 4·10 | 4·36 | 4·62 | 4·88 | 5·14 | 5·40 | 5·66 |
| $\frac{3}{8}$ | 4·53 | 4·84 | 5·16 | 5·47 | 5·78 | 6·09 | 6·41 | 6·72 |
| $\frac{7}{16}$ | 5·20 | 5·56 | 5·92 | 6·29 | 6·65 | 7·02 | 7·38 | 7·75 |
| $\frac{1}{2}$ | ... | ... | 6·67 | 7·08 | 7·50 | 7·92 | 8·33 | 8·75 |
| $\frac{9}{16}$ | ... | ... | 7·38 | 7·85 | 8·32 | 8·79 | 9·26 | 9·73 |
| $\frac{5}{8}$ | ... | ... | ... | 8·59 | 9·11 | 9·63 | 10·16 | 10·68 |
| $\frac{11}{16}$ | ... | ... | ... | ... | 10·03 | 10·62 | 11·20 | 11·78 |
| $\frac{3}{4}$ | ... | ... | ... | ... | ... | ... | ... | 12·50 |

| Average Thickness. | Sum of the Width and Depth in Inches. | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 6 | $6\frac{1}{2}$ | 7 | $7\frac{1}{2}$ | 8 | $8\frac{1}{2}$ | 9 | $9\frac{1}{2}$ |
| Inch. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. |
| $\frac{1}{4}$ | 4·79 | 5·21 | 5·63 | 6·04 | 6·46 | 6·88 | 7·29 | 7·71 |
| $\frac{5}{16}$ | 5·92 | 6·45 | 6·97 | 7·49 | 8·01 | 8·53 | 9·05 | 9·57 |
| $\frac{3}{8}$ | 7·03 | 7·66 | 8·28 | 8·91 | 9·53 | 10·16 | 10·78 | 11·41 |
| $\frac{7}{16}$ | 8·11 | 8·84 | 9·57 | 10·30 | 11·03 | 11·76 | 12·49 | 13·22 |
| $\frac{1}{2}$ | 9·17 | 10·00 | 10·83 | 11·67 | 12·50 | 13·33 | 14·17 | 15·00 |
| $\frac{9}{16}$ | 10·20 | 11·13 | 12·07 | 13·01 | 13·94 | 14·88 | 15·82 | 16·76 |
| $\frac{5}{8}$ | 11·19 | 12·24 | 13·28 | 14·32 | 15·36 | 16·41 | 17·45 | 18·49 |
| $\frac{11}{16}$ | 12·37 | 13·54 | 14·70 | 15·87 | 17·03 | 18·20 | 19·36 | 20·53 |
| $\frac{3}{4}$ | 13·13 | 14·38 | 15·63 | 16·88 | 18·13 | 19·38 | 20·63 | 21·88 |
| $\frac{7}{8}$ | 14·95 | 16·41 | 17·86 | 19·32 | 20·78 | 22·24 | 23·70 | 25·16 |
| 1 | ... | ... | ... | 21·67 | 23·33 | 25·00 | 26·67 | 28·33 |

TABLE 94.—ANGLE IRONS AND TEE IRONS: WEIGHT (*continued*).

| Average Thickness. | Sum of the Width and Depth in Inches. | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 10 | $10\frac{1}{2}$ | 11 | 12 | 13 | 14 | 15 | 16 |
| Inch. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. |
| $\frac{3}{8}$ | 12·03 | 12·66 | 13·28 | 14·53 | ... | ... | ... | ... |
| $\frac{7}{16}$ | 13·95 | 14·67 | 15·40 | 16·86 | 18·31 | 19·77 | 21·22 | 22·67 |
| $\frac{1}{2}$ | 15·83 | 16·67 | 17·50 | 19·17 | 20·84 | 22·50 | 24·17 | 25·84 |
| $\frac{9}{16}$ | 17·70 | 18·63 | 19·57 | 21·44 | 23·31 | 25·19 | 27·06 | 28·93 |
| $\frac{5}{8}$ | 19·53 | 20·57 | 21·61 | 23·70 | 25·78 | 27·87 | 29·95 | 32·03 |
| $\frac{11}{16}$ | 21·69 | 22·86 | 24·03 | 26·36 | 28·70 | 31·03 | 33·36 | 35·70 |
| $\frac{3}{4}$ | 23·13 | 24·38 | 25·63 | 28·13 | 30·63 | 33·13 | 35·63 | 38·13 |
| $\frac{7}{8}$ | 26·61 | 28·07 | 29·53 | 32·45 | 35·36 | 38·28 | 41·19 | 44·12 |
| 1 | 30·00 | 31·67 | 33·333 | 36·67 | 40·00 | 43·30 | 46 67 | 50·00 |

TABLE 95.—WEIGHT OF FLAT BAR STEEL.

Length, 1 Foot.

| Thickness. | Width. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | $\frac{1}{2}$ | $\frac{5}{8}$ | $\frac{3}{4}$ | $\frac{7}{8}$ | 1 | $1\frac{1}{8}$ | $1\frac{1}{4}$ | $1\frac{3}{8}$ | $1\frac{1}{2}$ |
| Inch. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. |
| $\frac{1}{8}$ | ·213 | ·266 | ·319 | ·372 | ·425 | ·478 | ·532 | ·584 | ·638 |
| $\frac{3}{16}$ | ·320 | ·399 | ·478 | ·558 | ·638 | ·717 | ·797 | ·877 | ·957 |
| $\frac{1}{4}$ | ·425 | ·532 | ·638 | ·744 | ·851 | ·960 | 1·06 | 1·17 | 1·28 |
| $\frac{5}{16}$ | ·532 | ·665 | ·797 | ·930 | 1·06 | 1·20 | 1·33 | 1·46 | 1·59 |
| $\frac{3}{8}$ | ·638 | ·797 | ·957 | 1·11 | 1·28 | 1·43 | 1·59 | 1·75 | 1·91 |
| $\frac{7}{16}$ | ·744 | ·930 | 1·12 | 1·30 | 1·49 | 1·67 | 1·86 | 2·05 | 2·23 |
| $\frac{1}{2}$ | ·851 | 1·06 | 1·28 | 1·49 | 1·70 | 1·91 | 2·13 | 2·34 | 2·55 |
| $\frac{9}{16}$ | ·957 | 1·20 | 1·43 | 1·67 | 1·91 | 2·15 | 2·39 | 2·63 | 2·87 |
| $\frac{5}{8}$ | 1·06 | 1·33 | 1·59 | 1·86 | 2·13 | 2·39 | 2·66 | 2·92 | 3·19 |
| $\frac{11}{16}$ | 1·17 | 1·46 | 1·75 | 2·05 | 2·34 | 2·63 | 2·92 | 3·21 | 3·51 |
| $\frac{3}{4}$ | 1·28 | 1·59 | 1·91 | 2·23 | 2·55 | 2·87 | 3·19 | 3·51 | 3·83 |
| $\frac{13}{16}$ | 1·38 | 1·73 | 2·07 | 2·42 | 2·76 | 3·11 | 3·45 | 3·70 | 4·15 |
| $\frac{7}{8}$ | 1·49 | 1·86 | 2·23 | 2·60 | 2·98 | 3·35 | 3·72 | 4·09 | 4·47 |
| $\frac{15}{16}$ | 1·59 | 1·99 | 2·39 | 2·79 | 3·19 | 3·59 | 3·99 | 4·39 | 4·78 |
| 1 | 1·70 | 2·13 | 2·55 | 2·98 | 3·40 | 3·83 | 4·25 | 4·68 | 5·10 |

TABLE 95.—WEIGHT OF FLAT BAR STEEL (*continued*).

| Thickness. | Width. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $1\frac{5}{8}$ | $1\frac{3}{4}$ | $1\frac{7}{8}$ | 2 | $2\frac{1}{8}$ | $2\frac{1}{4}$ | $2\frac{3}{8}$ | $2\frac{1}{2}$ | $2\frac{5}{8}$ | $2\frac{3}{4}$ |
| Inch. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. |
| $\frac{1}{8}$ | ·691 | ·744 | ·797 | ·851 | ·904 | ·958 | 1·01 | 1·06 | 1·11 | 1·16 |
| $\frac{3}{16}$ | 1·04 | 1·11 | 1·196 | 1·28 | 1·36 | 1·43 | 1·51 | 1·59 | 1·67 | 1·75 |
| $\frac{1}{4}$ | 1·38 | 1·49 | 1·59 | 1·70 | 1·81 | 1·91 | 2·02 | 2·13 | 2·23 | 2·34 |
| $\frac{5}{16}$ | 1·73 | 1·86 | 1·99 | 2·13 | 2·26 | 2·39 | 2·52 | 2·66 | 2·79 | 2·92 |
| $\frac{3}{8}$ | 2·07 | 2·23 | 2·39 | 2·55 | 2·71 | 2·87 | 3·03 | 3·19 | 3·35 | 3·51 |
| $\frac{7}{16}$ | 2·42 | 2·60 | 2·79 | 2·98 | 3·16 | 3·35 | 3·53 | 3·72 | 3·91 | 4·09 |
| $\frac{1}{2}$ | 2·76 | 2·98 | 3·19 | 3·40 | 3·61 | 3·83 | 4·04 | 4·25 | 4·46 | 4·68 |
| $\frac{9}{16}$ | 3·11 | 3·35 | 3·59 | 3·83 | 4·07 | 4·31 | 4·54 | 4·78 | 5·02 | 5·26 |
| $\frac{5}{8}$ | 3·45 | 3·72 | 3·99 | 4·25 | 4·52 | 4·78 | 5·05 | 5·31 | 5·58 | 5·84 |
| $\frac{11}{16}$ | 3·80 | 4·09 | 4·39 | 4·68 | 4·97 | 5·26 | 5·56 | 5·86 | 6·14 | 6·43 |
| $\frac{3}{4}$ | 4·14 | 4·46 | 4·78 | 5·10 | 5·42 | 5·74 | 6·06 | 6·38 | 6·69 | 7·01 |
| $\frac{13}{16}$ | 4·49 | 4·84 | 5·18 | 5·53 | 5·87 | 6·22 | 6·57 | 6·92 | 7·26 | 7·60 |
| $\frac{7}{8}$ | 4·83 | 5·21 | 5·58 | 5·96 | 6·32 | 6·79 | 7·07 | 7·44 | 7·81 | 8·18 |
| $\frac{15}{16}$ | 5·18 | 5·58 | 5·98 | 6·38 | 6·78 | 7·18 | 7·58 | 7·98 | 8·37 | 8·77 |
| 1 | 5·53 | 5·96 | 6·38 | 6·81 | 7·23 | 7·66 | 8·08 | 8·51 | 8·93 | 9·36 |

| Thickness. | Width. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $2\frac{7}{8}$ | 3 | $3\frac{1}{4}$ | $3\frac{1}{2}$ | $3\frac{3}{4}$ | 4 | $4\frac{1}{4}$ | $4\frac{1}{2}$ | $4\frac{3}{4}$ | 5 |
| Inch. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. |
| $\frac{1}{8}$ | 1·22 | 1·28 | 1·38 | 1·49 | 1·59 | 1·70 | ... | ... | ... | ... |
| $\frac{3}{16}$ | 1·83 | 1·91 | 2·07 | 2·23 | 2·39 | 2·55 | ... | ... | ... | ... |
| $\frac{1}{4}$ | 2·44 | 2·55 | 2·76 | 2·98 | 3·19 | 3·40 | 3·61 | 3·83 | 4·04 | 4·25 |
| $\frac{5}{16}$ | 3·06 | 3·19 | 3·45 | 3·72 | 3·98 | 4·25 | 4·51 | 4·78 | 5·05 | 5·32 |
| $\frac{3}{8}$ | 3·67 | 3·83 | 4·14 | 4·46 | 4·78 | 5·10 | 5·44 | 5·74 | 6·06 | 6·38 |
| $\frac{7}{16}$ | 4·28 | 4·46 | 4·83 | 5·21 | 5·58 | 5·95 | 6·32 | 6·70 | 7·07 | 7·44 |
| $\frac{1}{2}$ | 4·89 | 5·10 | 5·53 | 5·95 | 6·38 | 6·80 | 7·23 | 7·66 | 8·08 | 8·50 |
| $\frac{9}{16}$ | 5·50 | 5·74 | 6·22 | 6·70 | 7·18 | 7·66 | 8·13 | 8·61 | 9·09 | 9·57 |
| $\frac{5}{8}$ | 6·11 | 6·38 | 6·91 | 7·44 | 7·97 | 8·50 | 9·04 | 9·57 | 10·10 | 10·63 |
| $\frac{11}{16}$ | 6·72 | 7·02 | 7·60 | 8·19 | 8·78 | 9·36 | 9·94 | 10·52 | 11·11 | 11·70 |
| $\frac{3}{4}$ | 7·33 | 7·65 | 8·29 | 8·93 | 9·56 | 10·20 | 10·85 | 11·48 | 12·12 | 12·76 |
| $\frac{13}{16}$ | 7·95 | 8·29 | 8·98 | 9·68 | 10·37 | 11·06 | 11·75 | 12·44 | 13·13 | 13·82 |
| $\frac{7}{8}$ | 8·55 | 8·93 | 9·67 | 10·41 | 11·16 | 11·90 | 12·65 | 13·40 | 14·14 | 14·89 |
| $\frac{15}{16}$ | 9·17 | 9·57 | 10·37 | 11·16 | 11·96 | 12·76 | 13·56 | 14·35 | 15·15 | 15·95 |
| 1 | 9·78 | 10·21 | 11·06 | 11·91 | 12·76 | 13·68 | 14·46 | 15·31 | 16·16 | 17·01 |

TABLE 95.—WEIGHT OF FLAT BAR STEEL (*continued*).

| Thick-ness. | Width. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 5½ | 6 | 6½ | 7 | 8 | 9 | 10 | 11 | 12 |
| Inch. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. |
| ¼ | 4·68 | 5·10 | 5·53 | 5·95 | 6·80 | 7·66 | 8·51 | 9·36 | 10·21 |
| 5/16 | 5·84 | 6·38 | 6·91 | 7·44 | 8·50 | 9·57 | 10·63 | 11·70 | 12·76 |
| ⅜ | 7·02 | 7·66 | 8·29 | 8·93 | 10·20 | 11·48 | 12·76 | 14·04 | 15·31 |
| 7/16 | 8·19 | 8·93 | 9·68 | 10·42 | 11·90 | 13·39 | 14·89 | 16·37 | 17·86 |
| ½ | 9·36 | 10·21 | 11·06 | 11·91 | 13·60 | 15·31 | 17·01 | 18·71 | 20·42 |
| 9/16 | 10·53 | 11·48 | 12·44 | 13·40 | 15·30 | 17·23 | 19·14 | 21·05 | 22·97 |
| ⅝ | 11·70 | 12·76 | 13·82 | 14·89 | 17·00 | 19·14 | 21·27 | 23·39 | 25·52 |
| 11/16 | 12·87 | 14·04 | 15·20 | 16·37 | 18·70 | 21·05 | 23·39 | 25·73 | 28·07 |
| ¾ | 14·04 | 15·31 | 16·59 | 17·86 | 20·40 | 22·97 | 25·32 | 28·07 | 30·62 |
| 13/16 | 15·21 | 16·59 | 17·97 | 19·35 | 22·10 | 24·88 | 27·65 | 30·41 | 33·18 |
| ⅞ | 16·37 | 17·86 | 19·35 | 20·84 | 23·80 | 26·80 | 29·77 | 32·75 | 35·73 |
| 15/16 | 17·54 | 19·14 | 20·73 | 21·33 | 25·50 | 28·71 | 31·90 | 35·09 | 38·28 |
| 1 | 18·71 | 20·41 | 22·12 | 23·82 | 27·20 | 30·60 | 34·03 | 37·43 | 40·80 |

TABLE 96.—WEIGHT OF SQUARE STEEL.
Length, 1 Foot.

| Side of Square. | Weight. | Side of Square. | Weight. | Side of Square. | Weight. | Side of Square. | Weight. |
|---|---|---|---|---|---|---|---|
| Inches. | Lbs. | Inches. | Lbs. | Inches. | Lbs. | Inches. | Lbs. |
| ⅛ | ·053 | 11/16 | 1·61 | 1 7/32 | 5·06 | 2½ | 21·3 |
| 5/32 | ·083 | 23/32 | 1·76 | 1¼ | 5·32 | 2⅝ | 23·5 |
| 3/16 | ·120 | ¾ | 1·91 | 1 5/16 | 5·86 | 2¾ | 25·7 |
| 7/32 | ·163 | 25/32 | 2·08 | 1⅜ | 6·43 | 2⅞ | 28·1 |
| ¼ | ·213 | 13/16 | 2·25 | 1 7/16 | 7·03 | 3 | 30·6 |
| 9/32 | ·269 | 27/32 | 2·45 | 1½ | 7·71 | 3¼ | 35·9 |
| 5/16 | ·332 | ⅞ | 2·61 | 1 9/16 | 8·31 | 3½ | 41·7 |
| 11/32 | ·402 | 29/32 | 2·81 | 1⅝ | 8·99 | 3¾ | 47·8 |
| ⅜ | ·479 | 15/16 | 2·99 | 1 11/16 | 9·80 | 4 | 54·4 |
| 13/32 | ·562 | 31/32 | 3·19 | 1¾ | 10·4 | 4¼ | 61·5 |
| 7/16 | ·651 | 1 | 3·40 | 1 13/16 | 11·2 | 4½ | 68·9 |
| 15/32 | ·748 | 1 1/32 | 3·61 | 1⅞ | 12·0 | 4¾ | 76·8 |
| ½ | ·851 | 1 1/16 | 3·84 | 1 15/16 | 12·8 | 5 | 85·1 |
| 17/32 | ·960 | 1 3/32 | 4·11 | 2 | 13·6 | 5¼ | 93·8 |
| 9/16 | 1·08 | 1⅛ | 4·31 | 2⅛ | 15·4 | 5½ | 102·9 |
| 19/32 | 1·20 | 1 5/32 | 4·57 | 2¼ | 17·2 | 5¾ | 112·4 |
| ⅝ | 1·33 | 1 3/16 | 4·80 | 2⅜ | 19·2 | 6 | 122·5 |
| 21/32 | 1·47 | | | | | | |

TABLE 97.—WEIGHT OF ROUND STEEL.
Length, 1 Foot.

| Diam. | Weight. | Diam. | Weight. | Diam. | Weight. | Diam. | Weight. |
|---|---|---|---|---|---|---|---|
| Inches. | Lbs. | Inches. | Lbs. | Inches. | Lbs. | Inches. | Cwts. |
| $\frac{1}{8}$ | ·042 | 1 | 2·68 | $2\frac{3}{8}$ | 15·1 | 8 | 1·527 |
| $\frac{5}{32}$ | ·065 | $1\frac{1}{32}$ | 2·84 | $2\frac{7}{16}$ | 15·9 | $8\frac{1}{2}$ | 1·725 |
| $\frac{3}{16}$ | ·094 | $1\frac{1}{16}$ | 3·02 | $2\frac{1}{2}$ | 16·8 | 9 | 1·932 |
| $\frac{7}{32}$ | ·128 | $1\frac{3}{32}$ | 3·21 | $2\frac{5}{8}$ | 18·4 | $9\frac{1}{2}$ | 2·154 |
| $\frac{1}{4}$ | ·167 | $1\frac{1}{8}$ | 3·38 | $2\frac{3}{4}$ | 20·2 | 10 | 2·387 |
| $\frac{9}{32}$ | ·211 | $1\frac{5}{32}$ | 3·57 | $2\frac{7}{8}$ | 22·1 | $10\frac{1}{2}$ | 2·631 |
| $\frac{5}{16}$ | ·261 | $1\frac{3}{16}$ | 3·77 | 3 | 24·1 | 11 | 2·887 |
| $\frac{11}{32}$ | ·317 | $1\frac{7}{32}$ | 3·98 | $3\frac{1}{8}$ | 26·1 | $11\frac{1}{2}$ | 3·152 |
| $\frac{3}{8}$ | ·376 | $1\frac{1}{4}$ | 4·17 | $3\frac{1}{4}$ | 28·3 | 12 | 3·436 |
| $\frac{13}{32}$ | ·441 | $1\frac{9}{32}$ | 4·38 | $3\frac{3}{8}$ | 30·4 | $12\frac{1}{2}$ | 3·732 |
| $\frac{7}{16}$ | ·511 | $1\frac{5}{16}$ | 4·61 | $3\frac{1}{2}$ | 32·8 | 13 | 4·032 |
| $\frac{15}{32}$ | ·587 | $1\frac{11}{32}$ | 4·80 | $3\frac{5}{8}$ | 35·1 | $13\frac{1}{2}$ | 4·349 |
| $\frac{1}{2}$ | ·658 | $1\frac{3}{8}$ | 5·05 | $3\frac{3}{4}$ | 37·6 | 14 | 4·676 |
| $\frac{17}{32}$ | ·755 | $1\frac{7}{16}$ | 5·19 | $3\frac{7}{8}$ | 40·1 | $14\frac{1}{2}$ | 5·317 |
| $\frac{9}{16}$ | ·845 | $1\frac{1}{2}$ | 6·01 | 4 | 42·8 | 15 | 5·668 |
| $\frac{19}{32}$ | ·941 | $1\frac{9}{16}$ | 6·52 | $4\frac{1}{4}$ | 46·3 | $15\frac{1}{2}$ | 5·733 |
| $\frac{5}{8}$ | 1·04 | $1\frac{5}{8}$ | 7·05 | $4\frac{1}{2}$ | 54·1 | 16 | 6·108 |
| $\frac{21}{32}$ | 1·15 | $1\frac{11}{16}$ | 7·62 | $4\frac{3}{4}$ | 60·3 | $16\frac{1}{2}$ | 6·496 |
| $\frac{11}{16}$ | 1·29 | $1\frac{3}{4}$ | 8·19 | 5 | 66·9 | 17 | 6·896 |
| $\frac{23}{32}$ | 1·30 | $1\frac{13}{16}$ | 8·78 | $5\frac{1}{4}$ | 73·7 | $17\frac{1}{2}$ | 7·308 |
| $\frac{3}{4}$ | 1·50 | $1\frac{7}{8}$ | 9·39 | $5\frac{1}{2}$ | 80·9 | 18 | 7·731 |
| $\frac{25}{32}$ | 1·63 | $1\frac{15}{16}$ | 10·0 | $5\frac{3}{4}$ | 88·4 | 19 | 8·614 |
| $\frac{13}{16}$ | 1·77 | 2 | 10·7 | 6 | 96·2 | 20 | 9·545 |
| $\frac{27}{32}$ | 1·90 | $2\frac{1}{16}$ | 11·3 | | | 21 | 10·53 |
| $\frac{7}{8}$ | 2·04 | $2\frac{1}{8}$ | 12·0 | Inches. | Cwts. | 22 | 11·55 |
| $\frac{29}{32}$ | 2·20 | $2\frac{3}{16}$ | 12·9 | $6\frac{1}{2}$ | 1·008 | 23 | 12·63 |
| $\frac{15}{16}$ | 2·35 | $2\frac{1}{4}$ | 13·6 | 7 | 1·169 | 24 | 13·74 |
| $\frac{31}{32}$ | 2·51 | $2\frac{5}{16}$ | 14·3 | $7\frac{1}{2}$ | 1·342 | | |

TABLE 98.—STEEL PLATES: ORDINARY SIZES.

| Thickness. | Maximum Area. | Maximum Length. | Maximum Width. | Thickness. | Maximum Area. | Maximum Length. | Maximum Width. |
|---|---|---|---|---|---|---|---|
| Inch. | Sq. Ft. | Feet. | Feet. | Inch. | Sq. Ft. | Feet. | Feet. |
| $\frac{1}{16}$ | 28 | 14 | 4 | $\frac{7}{16}$ | 98 | 40 | 7 |
| $\frac{3}{32}$ | 31 | 18 | $4\frac{1}{2}$ | $\frac{1}{2}$ | 105 | 40 | $7\frac{1}{2}$ |
| $\frac{1}{8}$ | 40 | 22 | 5 | $\frac{5}{8}$ | 115 | 40 | $8\frac{1}{4}$ |
| $\frac{5}{32}$ | 50 | 25 | $5\frac{1}{4}$ | $\frac{3}{4}$ | 125 | 37 | $8\frac{3}{4}$ |
| $\frac{3}{16}$ | 65 | 30 | $5\frac{1}{2}$ | $\frac{7}{8}$ | 125 | 34 | $8\frac{3}{4}$ |
| $\frac{1}{4}$ | 72 | 33 | 6 | 1 | 125 | 31 | $8\frac{3}{4}$ |
| $\frac{5}{16}$ | 75 | 35 | $6\frac{1}{4}$ | $1\frac{1}{8}$ | 110 | 28 | $8\frac{3}{4}$ |
| $\frac{3}{8}$ | 85 | 38 | $6\frac{1}{2}$ | $1\frac{1}{4}$ | 110 | 25 | $8\frac{3}{4}$ |

TABLE 99.—WEIGHT PER SQUARE FOOT OF STEEL SHEETS AND PLATES.

(The Steel Pipe Company.)

| Thickness. | | | Weight per Square Foot. Pounds. | Thickness. | | | Weight per Square Foot. Pounds. |
|---|---|---|---|---|---|---|---|
| Inch. | Inch. | Imperial Standard Gauge. | | Inch. | Inch. | Imperial Standard Gauge. | |
| ·0625 | $\frac{1}{16}$ | ... | 2·55 | ·21875 | $\frac{7}{32}$ | ... | 8·97 |
| ·064 | ... | 16 | 2·61 | ·232 | ... | 4 | 9·46 |
| ·072 | ... | 15 | 2·94 | ·25 | $\frac{1}{4}$ | ... | 10·20 |
| ·080 | ... | 14 | 3·26 | ·252 | ... | 3 | 10·28 |
| ·092 | ... | 13 | 3·75 | ·276 | ... | 2 | 11·26 |
| ·09375 | $\frac{3}{32}$ | ... | 3·87 | ·300 | ... | 1 | 12·24 |
| ·104 | ... | 12 | 4·24 | ·3125 | $\frac{5}{16}$ | ... | 12·75 |
| ·116 | ... | 11 | 4·73 | ·375 | $\frac{3}{8}$ | ... | 15·30 |
| ·125 | $\frac{1}{8}$ | ... | 5·10 | ·4375 | $\frac{7}{16}$ | ... | 17·85 |
| ·128 | ... | 10 | 5·22 | ·500 | $\frac{1}{2}$ | ... | 20·40 |
| ·144 | ... | 9 | 5·87 | ·5625 | $\frac{9}{16}$ | ... | 22·95 |
| ·15625 | $\frac{5}{32}$ | ... | 6·37 | ·625 | $\frac{5}{8}$ | ... | 25·50 |
| ·160 | ... | 8 | 6·53 | ·6875 | $\frac{11}{16}$ | ... | 28·05 |
| ·176 | ... | 7 | 7·18 | ·75 | $\frac{3}{4}$ | ... | 30·60 |
| ·1875 | $\frac{3}{16}$ | ... | 7·65 | ·875 | $\frac{7}{8}$ | ... | 35·70 |
| ·192 | ... | 6 | 7·83 | 1·00 | 1 | ... | 40·80 |
| ·212 | ... | 5 | 8·65 | | | | |

TABLE 100.—CHISEL STEEL: WEIGHT.

Length, 1 Foot.

| Diameter across the Sides. | Weight. | | Diameter across the Sides. | Weight. | |
|---|---|---|---|---|---|
| | Hexagonal Section. | Octagonal Section. | | Hexagonal Section. | Octagonal Section. |
| Inches. | Pounds. | Pounds. | Inches. | Pounds. | Pounds. |
| $\frac{3}{8}$ | ·414 | ·396 | 1 | 2·94 | 2·82 |
| $\frac{1}{2}$ | ·736 | ·704 | $1\frac{1}{8}$ | 3·73 | 3·56 |
| $\frac{5}{8}$ | 1·15 | 1·10 | $1\frac{1}{4}$ | 4·60 | 4·40 |
| $\frac{3}{4}$ | 1·66 | 1·58 | $1\frac{3}{8}$ | 5·57 | 5·32 |
| $\frac{7}{8}$ | 2·25 | 2·16 | $1\frac{1}{2}$ | 6·63 | 6·34 |

OVAL FLAT SECTION.

| Width × Thickness. | Weight. |
|---|---|
| Inches. | Pounds. |
| $\frac{3}{4} \times \frac{3}{8}$ | ·853 |
| $1 \times \frac{1}{2}$ | 1·52 |
| $1\frac{1}{4} \times \frac{5}{8}$ | 2·37 |

TABLE 101.—SIZES, WEIGHTS, LENGTHS, AND BREAKING STRESS OF IRON WIRE.

Issued by the Iron and Steel Wire Manufacturers' Association, January 15, 1884.

(Imperial Standard Wire-Gauge.)

| Size on Wire Gauge. | Diameter. | | Sectional Area. | Weight of | | Length of Cwt. | Breaking Stress. | |
|---|---|---|---|---|---|---|---|---|
| | Inch. | Millimetres. | Sq. Ins. | 100 Yards. | Mile. | | Annealed. | Bright. |
| | | | | Lbs. | Lbs. | Yards. | Lbs. | Lbs. |
| 7/0 | ·500 | 12·7 | ·1963 | 193·4 | 3404 | 58 | 10470 | 15700 |
| 6/0 | ·464 | 11·8 | ·1691 | 166·5 | 2930 | 67 | 9017 | 13525 |
| 5/0 | ·432 | 11 | ·1466 | 144·4 | 2541 | 78 | 7814 | 11725 |
| 4/0 | ·400 | 10·2 | ·1257 | 123·8 | 2179 | 91 | 6702 | 10052 |
| 3/0 | ·372 | 9·4 | ·1087 | 107·1 | 1885 | 105 | 5796 | 8694 |
| 2/0 | ·348 | 8·8 | ·0951 | 93·7 | 1649 | 120 | 5072 | 7608 |
| 1/0 | ·324 | 8·2 | ·0824 | 81·2 | 1429 | 138 | 4397 | 6595 |
| 1 | ·300 | 7·6 | ·0707 | 69·6 | 1225 | 161 | 3770 | 5655 |
| 2 | ·276 | 7 | ·0598 | 58·9 | 1037 | 190 | 3190 | 4785 |
| 3 | ·252 | 6·4 | ·0499 | 49·1 | 864 | 228 | 2660 | 3990 |
| 4 | ·232 | 5·9 | ·0423 | 41·6 | 732 | 269 | 2254 | 3381 |
| 5 | ·212 | 5·4 | ·0353 | 34·8 | 612 | 322 | 1883 | 2824 |
| 6 | ·192 | 4·9 | ·0290 | 28·5 | 502 | 393 | 1544 | 2316 |
| 7 | ·176 | 4·5 | ·0243 | 24 | 422 | 467 | 1298 | 1946 |
| 8 | ·160 | 4·1 | ·0201 | 19·8 | 348 | 566 | 1072 | 1608 |
| 9 | ·144 | 3·7 | ·0163 | 16 | 282 | 700 | 869 | 1303 |
| 10 | ·128 | 3·3 | ·0129 | 12·7 | 223 | 882 | 687 | 1030 |
| 11 | ·116 | 3 | ·0106 | 10·4 | 183 | 1077 | 564 | 845 |
| 12 | ·104 | 2·6 | ·0085 | 8·4 | 148 | 1333 | 454 | 680 |
| 13 | ·092 | 2·3 | ·0066 | 6·5 | 114 | 1723 | 355 | 532 |
| 14 | ·080 | 2 | ·0050 | 5 | 88 | 2240 | 268 | 402 |
| 15 | ·072 | 1·8 | ·0041 | 4 | 70 | 2800 | 218 | 326 |
| 16 | ·064 | 1·6 | ·0032 | 3·2 | 56 | 3500 | 172 | 257 |
| 17 | ·056 | 1·4 | ·0025 | 2·4 | 42 | 4667 | 131 | 197 |
| 18 | ·048 | 1·2 | ·0018 | 1·8 | 32 | 6222 | 97 | 145 |
| 19 | ·040 | 1 | ·0013 | 1·2 | 21 | 9333 | 67 | 100 |
| 20 | ·036 | 0·9 | ·0010 | 1 | 18 | 11200 | 55 | 82 |

## Indian Government Telegraphs.

### TELEGRAPH WIRES FOR LINES AND CABLES.

The data for inspection as to size, weight, tensile strength, and ductility, for all sizes of telegraph wires in use by the Indian Government, are given in the Tables 102 and 103, for line wire and cable wire. The wires are of iron, galvanised. In testing the wire for tensile strength, it is loaded by direct weight vertically, and is required at first to lift a weight equal to $\frac{8}{10}$ths of the maximum proof load. If the wire supports the load without failure, the load is gradually augmented by four successive advances, until the wire fails or the maximum load is reached. Testing for ductility, the piece of wire, after failure by load, or after supporting the maximum load, is gripped by two vices and twisted. The vices are 6 inches apart for sizes above 150 pounds per mile; and 3 inches apart for sizes of 150 pounds or less. The number of twists applied is reduced as the proportional resistance to load is greater, according to the scale of loads and relative twists given in the Tables.

A margin of $1\frac{1}{2}$ per cent. deviation either way from the required weight of wire, weighing 600 pounds per mile and upwards is allowed; and for wires of less weight, 2 per cent. is allowed.

Weld joints are not allowed in cable-wire, except in the case of cable-wire weighing 900 pounds per mile, sent to Calcutta, in which, if in coils of from 400 to 500 pounds weight, one weld may be introduced.

The maximum resistances per inch of wires, at 60° F.—not to be exceeded—are as follows:—

| No. | Units. | No. | Units. |
|---|---|---|---|
| 1 | 4·5 | $9\frac{1}{2}$ | 18 |
| $3\frac{1}{2}$ | 6·5 | $12\frac{1}{2}$ | 36 |
| $4\frac{1}{2}$ | 7·25 | $15\frac{1}{2}$ | 72 |
| 5 | 8 | 16 | 90 |
| $5\frac{1}{2}$ | 9 | 16 | 108 |
| 7 | 12 | | |

The wires are to bear winding round bars of different diameters, without cracking, as follows:—

| Nos. | Bars. |
|---|---|
| $3\frac{1}{2}$ and $4\frac{1}{2}$ | 4 inches in diameter. |
| 5 „ $5\frac{1}{2}$ | $2\frac{1}{2}$ „ „ |
| 7 „ $9\frac{1}{2}$ | 2 „ „ |
| $12\frac{1}{2}$ „ $15\frac{1}{2}$ | 1 „ „ |
| 16 „ 17 | $\frac{1}{2}$ „ „ |

TABLE 102.—GALVANISED IRON TELEGRAPH WIRES: STANDARD SIZES, WEIGHTS AND TESTS.

(India Stores Department.)

LINE WIRE.

| Nominal Size. | Diameter. | Weight per Mile. | Weight of Ten Feet. | Tests for Strength and Ductility. | | | | | | | | | | Weight of each Coil. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Load. | Twists. | Load. | Twists. | Load. | Twists. | Load. | Twists. | Load. | Twists. | Minimum. | Maximum. |
| Nos. | Inch. | Lbs. | Lbs. | Lbs. | | Lbs. | | Lbs. | | Lbs. | | Lbs. | | Lbs. | Lbs. |
| 1 | ·2960 | 1200 | 2·272 | 3700 | 11 | 3800 | 10 | 3900 | 9 | 4000 | 8 | 4100 | 7 | 100 | 120 |
| 3½ | ·2547 | 900 | 1·704 | 2775 | 14 | 2850 | 13 | 2925 | 12 | 3000 | 11 | 3076 | 10 | 95 | 105 |
| 4½ | ·2325 | 750 | 1·420 | 2312 | 15 | 2375 | 14 | 2437 | 13 | 2500 | 12 | 2562 | 11 | 95 | 105 |
| 5 | ·2205 | 675 | 1·278 | 2081 | 16 | 2137 | 15 | 2193 | 14 | 2250 | 13 | 2306 | 12 | 95 | 105 |
| 5½ | ·2079 | 600 | 1·136 | 1850 | 17 | 1900 | 16 | 1950 | 15 | 2000 | 14 | 2050 | 13 | 95 | 105 |
| 7 | ·1801 | 450 | ·852 | 1388 | 19 | 1425 | 18 | 1460 | 17 | 1500 | 16 | 1538 | 15 | 80 | 105 |
| 9½ | ·1470 | 300 | ·568 | 925 | 24 | 950 | 22 | 975 | 21 | 1000 | 19 | 1025 | 18 | 70 | 80 |
| 12½ | ·1039 | 150 | ·284 | 462 | 17 | 475 | 16 | 487 | 15 | 500 | 14 | 512 | 13 | 70 | 80 |
| 15½ | ·0735 | 75 | ·142 | 208 | 24 | 214 | 23 | 219 | 21 | 225 | 19 | 231 | 18 | 35 | 40 |
| 16 | ·0657 | 60 | ·113 | 167 | 26 | 171 | 25 | 176 | 23 | 180 | 22 | 185 | 20 | 35 | 40 |
| 17 | ·0600 | 50 | ·095 | 152 | 30 | 157 | 28 | 162 | 26 | 167 | 24 | 172 | 22 | 35 | 40 |

TABLE 103.—GALVANISED TELEGRAPH WIRES: STANDARD SIZES, WEIGHTS AND TESTS.

(India Stores Department.)

CABLE WIRE.

| Nominal Size. | Weight per Mile. | Tests for Strength and Ductility. | | | | | | | | | | Weight of each Coil. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Load. | Twists. | Load. | Twists. | Load. | Twists. | Load. | Twists. | Load. | Twists. | Minimum. | Maximum. |
| No. | Lbs. | Lbs. | | Lbs. | | Lbs. | | Lbs. | | Lbs. | | Lbs. | Lbs. |
| 3 | 925 | 3090 | 10 | 3165 | 9 | 3240 | 8 | 3315 | 7 | 3390 | 6 | 210 | 230 |
| 3½ | 900 | 3000 | 10 | 3075 | 9 | 3150 | 8 | 3225 | 7 | 3300 | 6 | 210 | 230 |
| 4½ | 750 | 2500 | 11 | 2562 | 10 | 2625 | 9 | 2687 | 8 | 2750 | 7 | 150 | 160 |
| 5½ | 600 | 2000 | 12 | 2050 | 11 | 2100 | 10 | 2150 | 9 | 2200 | 8 | 150 | 160 |
| 7 | 450 | 1500 | 14 | 1540 | 13 | 1580 | 12 | 1620 | 11 | 1660 | 10 | 120 | 130 |
| 9½ | 300 | 1000 | 17 | 1025 | 16 | 1050 | 15 | 1075 | 14 | 1100 | 13 | 120 | 130 |

## Table 104.—Sheet and Hoop-Iron Gauge.

Issued by the South Staffordshire Iron Masters' Association, March 1, 1884.

| Parts of Inch. | No. on Gauge. | Thickness. | Weight of One Square Foot. | | Parts of Inch. | No. on Gauge. | Thickness. | Weight of One Square Foot. | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Iron. | Steel. | | | | Iron. | Steel. |
| Inch. | | Inch. | Lbs. | | Inch. | | Inch. | Lbs. | |
| 1 | 15° | 1·000 | 40 | 40·83 | | 20 | ·0392 | 1·57 | 1·60 |
| | 14° | 0·9583 | 38·33 | 39·13 | | 21 | ·0349 | 1·40 | 1·43 |
| | 13° | ·9167 | 36·67 | 37·44 | $\frac{1}{32}$ | 22 | ·0312 | 1·25 | 1·28 |
| $\frac{7}{8}$ | 12° | ·8750 | 35·00 | 35·73 | | 23 | ·0278 | 1·11 | 1·13 |
| | 11° | ·8333 | 33·33 | 34·03 | | 24 | ·0247 | ·992 | 1·01 |
| | 10° | ·7917 | 31·67 | 32·33 | | 25 | ·0220 | ·883 | ·901 |
| $\frac{3}{4}$ | 9° | ·750 | 30·00 | 30·63 | | 26 | ·0196 | ·784 | ·800 |
| | 8° | ·7083 | 28·33 | 28·92 | | 27 | ·0174 | ·696 | ·710 |
| | 7° | ·6666 | 26·67 | 27·23 | $\frac{1}{64}$ | 28 | ·015625 | ·625 | ·638 |
| $\frac{5}{8}$ | 6° | ·625 | 25·00 | 25·52 | | 29 | ·0139 | ·556 | ·568 |
| | 5° | ·5883 | 23·33 | 23·82 | | 30 | ·0123 | ·492 | ·502 |
| | 4° | ·5416 | 21·67 | 22·12 | | 31 | ·0110 | ·440 | ·449 |
| $\frac{1}{2}$ | 3° | ·500 | 20·00 | 20·42 | | 32 | ·0098 | ·392 | ·400 |
| | 2° | ·4452 | 18·33 | 18·69 | | 33 | ·0087 | ·349 | ·356 |
| | 1° | ·3964 | 16·67 | 17·02 | | 34 | ·0077 | ·308 | ·314 |
| | 1 | ·3532 | 15·00 | 15·31 | | 35 | ·0069 | ·276 | ·282 |
| | 2 | ·3147 | 13·33 | 13·61 | | 36 | ·0061 | ·244 | ·249 |
| | 3 | ·2804 | 11·67 | 12·01 | | 37 | ·0054 | ·216 | ·221 |
| $\frac{1}{4}$ | 4 | ·250 | 10·00 | 10·21 | | 38 | ·0048 | ·192 | ·196 |
| | 5 | ·2225 | 8·90 | 9·08 | | 39 | ·0043 | ·172 | ·176 |
| | 6 | ·1981 | 7·92 | 8·09 | | 40 | ·00386 | ·154 | ·157 |
| | 7 | ·1764 | 7·06 | 7·20 | | 41 | ·00343 | ·138 | ·140 |
| | 8 | ·1570 | 6·38 | 6·52 | | 42 | ·00306 | ·123 | ·126 |
| | 9 | ·1398 | 6·51 | 6·65 | | 43 | ·00272 | ·109 | ·111 |
| $\frac{1}{8}$ | 10 | ·1250 | 5·00 | 5·10 | | 44 | ·00242 | ·097 | ·099 |
| | 11 | ·1113 | 4·45 | 4·54 | | 45 | ·00215 | ·086 | ·088 |
| | 12 | ·0991 | 3·97 | 4·05 | | 46 | ·00192 | ·077 | ·079 |
| | 13 | ·0882 | 3·53 | 3·55 | | 47 | ·00170 | ·068 | ·069 |
| | 14 | ·0785 | 3·14 | 3·21 | | 48 | ·00152 | ·061 | ·062 |
| | 15 | ·0699 | 2·80 | 2·86 | | 49 | ·00135 | ·054 | ·055 |
| $\frac{1}{16}$ | 16 | ·0625 | 2·50 | 2·55 | | 50 | ·00120 | ·048 | ·049 |
| | 17 | ·0556 | 2·23 | 2·27 | | 51 | ·00107 | ·043 | ·044 |
| | 18 | ·0495 | 1·98 | 2·02 | | 52 | ·00095 | ·038 | ·039 |
| | 19 | ·0440 | 1·76 | 1·80 | | | | | |

TABLE 105.—LAP-WELDED
(Andrew and

WEIGHT OF ONE

| Thickness by Imperial Wire Gauge. | | | External | | | |
|---|---|---|---|---|---|---|
| | | | 1 | $1\frac{1}{8}$ | $1\frac{1}{4}$ | $1\frac{3}{8}$ |
| Wire Gauge. | Inches. | Millimetres. | Lbs. | Lbs. | Lbs. | Lbs. |
| 16 | ·064 | 1·626 | 0·627 | 0·711 | ... | ... |
| 15 | ·072 | 1·829 | 0·700 | 0·794 | 0·888 | 0·982 |
| 14 | ·080 | 2·032 | 0·771 | 0·875 | 0·980 | 1·085 |
| 13 | ·092 | 2·337 | 0·875 | 0·995 | **1·116** | **1·236** |
| 12 | ·104 | 2·642 | 0·976 | 1·112 | 1·248 | 1·384 |
| 11 | ·116 | 2·946 | 1·074 | 1·226 | 1·377 | 1·529 |
| 10 | ·128 | 3·251 | 1·169 | 1·336 | 1·504 | 1·671 |
| 9 | ·144 | 3·658 | 1·291 | 1·479 | 1·668 | 1·856 |
| 8 | ·160 | 4·064 | 1·407 | 1·617 | 1·826 | 2·036 |
| 7 | ·176 | 4·470 | 1·519 | 1·749 | 1·979 | 2·210 |
| 6 | ·192 | 4·877 | 1·624 | 1·876 | 2·127 | 2·378 |
| 5 | ·212 | 5·385 | 1·749 | 2·027 | 2·304 | 2·582 |
| 4 | ·232 | 5·893 | 1·866 | 2·169 | 2·473 | 2·777 |
| 3 | ·252 | 6·401 | 1·974 | 2·304 | 2·634 | 2·963 |
| 2 | ·276 | 7·010 | 2·092 | 2·454 | 2·815 | 3·176 |
| 1 | ·300 | 7·620 | 2·199 | 2·592 | 2·984 | 3·377 |
| $\frac{1}{8}$ in. | ·125 | 3·175 | 1·145 | 1·309 | 1·473 | 1·636 |
| $\frac{3}{16}$ „ | ·187 | 4·762 | 1·595 | 1·841 | 2·086 | 2·332 |
| $\frac{1}{4}$ „ | ·250 | 6·350 | 1·963 | 2·291 | 2·618 | 2·945 |
| $\frac{5}{16}$ „ | ·313 | 7·937 | 2·250 | 2·659 | 3·068 | 3·477 |
| $\frac{3}{8}$ „ | ·375 | 9·525 | 2·454 | 2·945 | 3·436 | 3·927 |
| $\frac{7}{16}$ „ | ·437 | 11·112 | 2·577 | 3·150 | 3·723 | 4·295 |
| $\frac{1}{2}$ „ | ·500 | 12·700 | 2·618 | 3·272 | 3·927 | 4·581 |

*Note.*—The most common thick-

* The weight per lineal foot of a steel tube is given by multiply-

IRON BOILER TUBES.*
James Stewart.)

FOOT IN LENGTH.

| Diameter in Inches. | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1½ | 1⅝ | 1¾ | 1⅞ | 2 | 2⅛ | 2¼ | 2⅜ |
| Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. |
| ... | ... | ... | ... | ... | ... | ... | ... |
| 1·077 | 1·171 | 1·265 | 1·359 | ... | ... | ... | ... |
| 1·190 | 1·294 | 1·399 | 1·504 | 1·608 | 1·713 | 1·818 | ... |
| **1·356** | **1·477** | **1·597** | **1·718** | 1·838 | 1·959 | 2·079 | 2·199 |
| 1·520 | 1·656 | 1·793 | 1·929 | **2·065** | **2·201** | **2·337** | 2·473 |
| 1·681 | 1·833 | 1·985 | 2·137 | 2·288 | 2·440 | 2·592 | **2·744** |
| 1·839 | 2·007 | 2·174 | 2·342 | 2·509 | 2·677 | 2·844 | 3·012 |
| 2·045 | 2·233 | 2·422 | 2·610 | 2·799 | 2·987 | 3·176 | 3·364 |
| 2·245 | 2·455 | 2·664 | 2·873 | 3·083 | 3·292 | 3·502 | 3·711 |
| 2·440 | 2·671 | 2·901 | 3·131 | 3·362 | 3·592 | 3·822 | 4·053 |
| 2·630 | 2·881 | 3·132 | 3·384 | 3·635 | 3·886 | 4·138 | 4·389 |
| 2·859 | 3·137 | 3·414 | 3·692 | 3·969 | 4·247 | 4·524 | 4·802 |
| 3·081 | 3·384 | 3·688 | 3·992 | 4·295 | 4·599 | 4·903 | 5·206 |
| 3·293 | 3·623 | 3·953 | 4·283 | 4·613 | 4·943 | 5·273 | 5·602 |
| 3·538 | 3·899 | 4·260 | 4·621 | 4·983 | 5·344 | 5·705 | 6·067 |
| 3·770 | 4·163 | 4·555 | 4·948 | 5·341 | 5·733 | 6·126 | 6·519 |
| 1·800 | 1·963 | 2·127 | 2·291 | 2·454 | 2·618 | 2·782 | 2·945 |
| 2·577 | 2·822 | 3·068 | 3·313 | 3·559 | 3·804 | 4·050 | 4·295 |
| 3·272 | 3·600 | 3·927 | 4·254 | 4·581 | 4·909 | 5·236 | 5·563 |
| 3·886 | 4·295 | 4·704 | 5·113 | 5·522 | 5·931 | 6·340 | 6·749 |
| 4·418 | 4·909 | 5·400 | 5·890 | 6·381 | 6·872 | 7·363 | 7·854 |
| 4·868 | 5·440 | 6·013 | 6·586 | 7·159 | 7·731 | 8·304 | 8·877 |
| 5·236 | 5·890 | 6·545 | 7·199 | 7·854 | 8·508 | 9·163 | 9·817 |

nesses are printed in dark figures.
ing the tabular weight of a like wrought-iron tube by 1·021.

TABLE 105.—LAP-WELDED IRON
(Andrew and

WEIGHT OF ONE

| Thickness by Imperial Wire Gauge. | External | | | | | | |
|---|---|---|---|---|---|---|---|
| | $2\frac{1}{2}$ | $2\frac{5}{8}$ | $2\frac{3}{4}$ | $2\frac{7}{8}$ | 3 | $3\frac{1}{8}$ | $3\frac{1}{4}$ |
| Wire Gauge. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. |
| 16 | ... | ... | ... | ... | ... | ... | ... |
| 15 | ... | ... | ... | ... | ... | ... | ... |
| 14 | ... | ... | ... | ... | ... | ... | ... |
| 13 | 2·320 | 2·440 | 2·561 | 2·681 | 2·802 | ... | ... |
| 12 | 2·609 | 2·745 | 2·882 | 3·018 | 3·154 | 3·290 | 3·426 |
| 11 | **2·896** | **3·048** | **3·200** | **3·351** | **3·503** | 3·655 | 3·807 |
| 10 | 3·179 | 3·347 | 3·514 | 3·682 | 3·850 | **4·017** | **4·185** |
| 9 | 3·553 | 3·741 | 3·930 | 4·118 | 4·307 | 4·495 | 4·684 |
| 8 | 3·921 | 4·130 | 4·339 | 4·549 | 4·758 | 4·968 | 5·177 |
| 7 | 4·283 | 4·514 | 4·744 | 4·974 | 5·205 | 5·435 | 5·665 |
| 6 | 4·640 | 4·892 | 5·143 | 5·394 | 5·646 | 5·897 | 6·148 |
| 5 | 5·079 | 5·357 | 5·634 | 5·912 | 6·189 | 6·467 | 6·744 |
| 4 | 5·510 | 5·814 | 6·117 | 6·421 | 6·725 | 7·028 | 7·332 |
| 3 | 5·932 | 6·262 | 6·592 | 6·922 | 7·252 | 7·582 | 7·911 |
| 2 | 6·428 | 6·789 | 7·150 | 7·512 | 7·873 | 8·234 | 8·596 |
| 1 | 6·911 | 7·304 | 7·697 | 8·090 | 8·482 | 8·875 | 9·268 |
| $\frac{1}{8}$ in. | 3·109 | 3·272 | 3·436 | 3·600 | 3·763 | 3·927 | 4·091 |
| $\frac{3}{16}$ " | 4·541 | 4·786 | 5·031 | 5·277 | 5·522 | 5·768 | 6·013 |
| $\frac{1}{4}$ " | 5·890 | 6·218 | 6·545 | 6·872 | 7·200 | 7·527 | 7·854 |
| $\frac{5}{16}$ " | 7·159 | 7·568 | 7·977 | 8·386 | 8·795 | 9·204 | 9·613 |
| $\frac{3}{8}$ " | 8·345 | 8·836 | 9·327 | 9·818 | 10·308 | 10·799 | 11·290 |
| $\frac{7}{16}$ " | 9·449 | 10·022 | 10·595 | 11·167 | 11·740 | 12·313 | 12·885 |
| $\frac{1}{2}$ " | 10·472 | 11·126 | 11·781 | 12·435 | 13·090 | 13·744 | 14·399 |

*Note.*—The most common thick-

* The weight per lineal foot of a steel tube is given by multi-

BOILER TUBES*—*continued.*
James Stewart.)

FOOT IN LENGTH.

Diameter in Inches.

| $3\frac{3}{8}$ | $3\frac{1}{2}$ | $3\frac{5}{8}$ | $3\frac{3}{4}$ | $3\frac{7}{8}$ | 4 | $4\frac{1}{4}$ | $4\frac{1}{2}$ | $4\frac{3}{4}$ |
|---|---|---|---|---|---|---|---|---|
| Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. |
| ... | ... | ... | ... | ... | ... | ... | ... | ... |
| ... | ... | ... | ... | ... | ... | ... | ... | ... |
| ... | ... | ... | ... | ... | ... | ... | ... | ... |
| ... | ... | ... | ... | ... | ... | ... | ... | ... |
| 3·562 | 3·698 | 3·835 | 3·971 | 4·107 | ... | ... | ... | ... |
| 3·959 | 4·111 | 4·262 | 4·414 | 4·566 | 4·718 | 5·022 | 5·325 | ... |
| **4·352** | **4·520** | **4·687** | **4·855** | 5·022 | 5·190 | 5·525 | 5·860 | 6·195 |
| 4·872 | 5·061 | 5·249 | 5·438 | **5·626** | **5·815** | **6·192** | **6·569** | 6·946 |
| 5·387 | 5·596 | 5·806 | 6·015 | 6·224 | 6·434 | 6·853 | 7·272 | **7·690** |
| 5·896 | 6·126 | 6·357 | 6·587 | 6·817 | 7·048 | 7·509 | 7·969 | 8·430 |
| 6·400 | 6·651 | 6·902 | 7·154 | 7·405 | 7·656 | 8·159 | 8·662 | 9·164 |
| 7·022 | 7·299 | 7·577 | 7·854 | 8·132 | 8·410 | 8·965 | 9·520 | 10·075 |
| 7·636 | 7·940 | 8·243 | 8·547 | 8·851 | 9·154 | 9·762 | 10·369 | 10·976 |
| 8·241 | 8·571 | 8·901 | 9·231 | 9·561 | 9·891 | 10·550 | 11·210 | 11·870 |
| 8·957 | 9·318 | 9·679 | 10·041 | 10·402 | 10·763 | 11·486 | 12·208 | 12·931 |
| 9·660 | 10·053 | 10·446 | 10·838 | 11·231 | 11·624 | 12·409 | 13·195 | 13·980 |
| 4·254 | 4·418 | 4·581 | 4·745 | 4·908 | 5·072 | 5·400 | 5·727 | 6·054 |
| 6·259 | 6·504 | 6·750 | 6·995 | 7·240 | 7·486 | 7·977 | 8·468 | 8·959 |
| 8·181 | 8·508 | 8·836 | 9·163 | 9·490 | 9·817 | 10·472 | 11·126 | 11·781 |
| 10·022 | 10·431 | 10·840 | 11·249 | 11·658 | 12·067 | 12·885 | 13·704 | 14·522 |
| 11·781 | 12·272 | 12·763 | 13·254 | 13·745 | 14·235 | 15·217 | 16·199 | 17·181 |
| 13·458 | 14·031 | 14·604 | 15·176 | 15·749 | 16·322 | 17·467 | 18·612 | 19·758 |
| 15·053 | 15·708 | 16·362 | 17·017 | 17·671 | 18·326 | 19·635 | 20·944 | 22·253 |

nesses are printed in dark figures.
plying the tabular weight of a like wrought-iron tube by 1·021.

TABLE 105.—LAP-WELDED IRON
(Andrew and

WEIGHT OF ONE

| Thickness by Imperial Wire Gauge. | External | | | | | | |
|---|---|---|---|---|---|---|---|
| | 5 | 5¼ | 5½ | 5¾ | 6 | 6¼ | 6½ |
| Wire Gauge. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. |
| 16 | ... | ... | ... | ... | ... | ... | ... |
| 15 | ... | ... | ... | ... | ... | ... | ... |
| 14 | ... | ... | ... | ... | ... | ... | ... |
| 13 | ... | ... | ... | ... | ... | ... | ... |
| 12 | ... | ... | ... | ... | ... | ... | ... |
| 11 | ... | ... | ... | ... | ... | ... | ... |
| 10 | 6·530 | 6·866 | ... | ... | ... | ... | ... |
| 9 | 7·323 | 7·700 | 8·077 | 8·454 | 8·831 | 9·208 | 9·585 |
| 8 | **8·109** | **8·528** | 8·947 | 9·366 | 9·785 | 10·204 | 10·623 |
| 7 | 8·891 | 9·352 | **9·812** | **10·273** | **10·734** | **11·195** | **11·655** |
| 6 | 9·667 | 10·170 | 10·672 | 11·175 | 11·678 | 12·180 | 12·683 |
| 5 | 10·630 | 11·185 | 11·740 | 12·295 | 12·850 | 13·405 | 13·960 |
| 4 | 11·584 | 12·191 | 12·798 | 13·406 | 14·013 | 14·621 | 15·228 |
| 3 | 12·530 | 13·189 | 13·849 | 14·509 | 15·169 | 15·828 | 16·488 |
| 2 | 13·654 | 14·376 | 15·099 | 15·821 | 16·544 | 17·266 | 17·989 |
| 1 | 14·765 | 15·551 | 16·336 | 17·122 | 17·907 | 18·692 | 19·478 |
| $\frac{1}{8}$ in. | 6·381 | 6·709 | 7·036 | 7·363 | 7·690 | 8·017 | 8·345 |
| $\frac{3}{16}$ ,, | 9·450 | 9·940 | 10·431 | 10·922 | 11·413 | 11·904 | 12·395 |
| $\frac{1}{4}$ ,, | 12·435 | 13·090 | 13·744 | 14·399 | 15·053 | 15·708 | 16·362 |
| $\frac{5}{16}$ ,, | 15·340 | 16·158 | 16·976 | 17·794 | 18·612 | 19·430 | 20·249 |
| $\frac{3}{8}$ ,, | 18·162 | 19·144 | 20·126 | 21·108 | 22·090 | 23·071 | 24·053 |
| $\frac{7}{16}$ ,, | 20·903 | 22·048 | 23·194 | 24·339 | 25·485 | 26·630 | 27·775 |
| $\frac{1}{2}$ ,, | 23·562 | 24·871 | 26·180 | 27·489 | 28·798 | 30·107 | 31·416 |

*Note.*—The most common thick-

* The weight per lineal foot of a steel tube is given by multi-

BOILER TUBES *—*continued.*
James Stewart.)

FOOT IN LENGTH.

Diameter in Inches.

| $6\frac{3}{4}$ | 7 | $7\frac{1}{4}$ | $7\frac{1}{2}$ | $7\frac{3}{4}$ | 8 | $8\frac{1}{4}$ | $8\frac{1}{2}$ | $8\frac{3}{4}$ |
|---|---|---|---|---|---|---|---|---|
| Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. |
| ... | ... | ... | ... | ... | ... | ... | ... | ... |
| ... | ... | ... | ... | ... | ... | ... | ... | ... |
| ... | ... | ... | ... | ... | ... | ... | ... | ... |
| ... | ... | ... | ... | ... | ... | ... | ... | ... |
| ... | ... | ... | ... | ... | ... | ... | ... | ... |
| ... | ... | ... | ... | ... | ... | ... | ... | ... |
| ... | ... | ... | ... | ... | ... | ... | ... | ... |
| 9·962 | 10·339 | ... | ... | ... | ... | ... | ... | ... |
| 11·042 | 11·460 | ... | ... | ... | ... | ... | ... | ... |
| **12·116** | **12·577** | 13·038 | 13·499 | 13·959 | 14·420 | 14·880 | 15·345 | 15·815 |
| 13·186 | 13·688 | 14·191 | 14·694 | 15·196 | 15·699 | 16·204 | 16·710 | 17·216 |
| 14·515 | 15·070 | **15·625** | **16·180** | **16·735** | **17·290** | 17·845 | 18·400 | 18·955 |
| 15·835 | 16·443 | 17·050 | 17·658 | 18·265 | 18·872 | 19·480 | 20·087 | 20·694 |
| 17·148 | 17·807 | 18·467 | 19·127 | 19·787 | 20·446 | **21·106** | **21·766** | **22·426** |
| 18·712 | 19·434 | 20·157 | 20·879 | 21·602 | 22·324 | 23·047 | 23·769 | 24·492 |
| 20·263 | 21·048 | 21·834 | 22·619 | 23·405 | 24·190 | 24·976 | 25·761 | 26·546 |
| 8·672 | 8·999 | 9·327 | 9·654 | 9·981 | 10·308 | 10·636 | 10·963 | 11·290 |
| 12·886 | 13·376 | 13·867 | 14·358 | 14·849 | 15·340 | 15·831 | 16·322 | 16·813 |
| 17·017 | 17·671 | 18·326 | 18·980 | 19·635 | 20·289 | 20·944 | 21·598 | 22·253 |
| 21·067 | 21·885 | 22·703 | 23·521 | 24·339 | 25·157 | 25·975 | 26·794 | 27·612 |
| 25·035 | 26·017 | 26·998 | 27·980 | 28·962 | 29·944 | 30·925 | 31·907 | 32·889 |
| 28·921 | 30·066 | 31·212 | 32·357 | 33·502 | 34·648 | 35·793 | 36·938 | 38·084 |
| 32·725 | 34·034 | 35·343 | 36·652 | 37·961 | 39·270 | 40·579 | 41·888 | 43·197 |

nesses are printed in dark figures.
plying the tabular weight of a like wrought-iron tube by 1·021.

TABLE 105.—LAP-WELDED IRON
(Andrew and

WEIGHT OF ONE

| Thickness by Imperial Wire Gauge. | | | External | | |
|---|---|---|---|---|---|
| | | | 9 | 9¼ | 9½ |
| Wire Gauge. | Inches. | Millimetres. | Lbs. | Lbs. | Lbs. |
| 16 | ·064 | 1·626 | ... | ... | ... |
| 15 | ·072 | 1·829 | ... | ... | ... |
| 14 | ·080 | 2·032 | ... | ... | ... |
| 13 | ·092 | 2·337 | ... | ... | ... |
| 12 | ·104 | 2·642 | ... | ... | ... |
| 11 | ·116 | 2·946 | ... | ... | ... |
| 10 | ·128 | 3·251 | ... | ... | ... |
| 9 | ·144 | 3·658 | ... | ... | ... |
| 8 | ·160 | 4·064 | ... | ... | ... |
| 7 | ·176 | 4·470 | 16·290 | 16·770 | 17·255 |
| 6 | ·192 | 4·877 | 17·722 | 18·230 | 18·738 |
| 5 | ·212 | 5·385 | 19·510 | 20·065 | 20·620 |
| 4 | ·232 | 5·893 | 21·302 | 21·909 | 22·517 |
| 3 | ·252 | 6·401 | **23·085** | **23·745** | **24·405** |
| 2 | ·276 | 7·010 | 25·215 | 25·937 | 26·660 |
| 1 | ·300 | 7·620 | 27·332 | 28·117 | 28·903 |
| ⅛ in. | ·125 | 3·175 | 11·617 | 11·945 | 12·272 |
| $\frac{3}{16}$ ,, | ·187 | 4·762 | 17·303 | 17·794 | 18·285 |
| ¼ ,, | ·250 | 6·350 | 22·907 | 23·562 | 24·216 |
| $\frac{5}{16}$ ,, | ·313 | 7·937 | 28·430 | 29·248 | 30·066 |
| ⅜ ,, | ·375 | 9·525 | 33·871 | 34·852 | 35·834 |
| $\frac{7}{16}$ ,, | ·437 | 11·112 | 39·229 | 40·375 | 41·520 |
| ½ ,, | ·500 | 12·700 | 44·506 | 45·815 | 47·124 |

*Note.*—The most common thick-
The weight per lineal foot of a steel tube is given by multi-

BOILER TUBES *—*continued.*
James Stewart.)

FOOT IN LENGTH.

Diameter in Inches.

| 9¾ | 10 | 10¼ | 10½ | 10¾ | 11 | 11½ | 12 |
|---|---|---|---|---|---|---|---|
| Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. |
| ... | ... | ... | ... | ... | ... | ... | ... |
| ... | ... | ... | ... | ... | ... | ... | ... |
| ... | ... | ... | ... | ... | ... | ... | ... |
| ... | ... | ... | ... | ... | ... | ... | ... |
| ... | ... | ... | ... | ... | ... | ... | ... |
| ... | ... | ... | ... | ... | ... | ... | ... |
| ... | ... | ... | ... | ... | ... | ... | ... |
| ... | ... | ... | ... | ... | ... | ... | ... |
| ... | ... | ... | ... | ... | ... | ... | ... |
| 17·745 | 18·240 | ... | ... | ... | ... | ... | ... |
| 19·250 | 19·760 | ... | ... | ... | ... | ... | ... |
| 21·175 | 21·730 | ... | ... | ... | ... | ... | ... |
| 23·124 | 23·731 | 24·35 | 25·00 | 25·70 | 26·45 | 28·00 | 29·50 |
| **25·065** | **25·724** | 26·28 | 26·88 | 27·51 | 28·15 | 29·45 | 30·80 |
| 27·382 | 28·105 | **28·80** | **29·50** | 30·22 | 30·95 | 32·45 | 33·95 |
| 29·688 | 30·463 | 31·30 | 32·17 | **33·07** | **34·00** | **35·95** | **38·00** |
| 12·599 | 12·926 | 13·25 | 13·60 | 14·00 | 14·43 | 15·30 | 16·20 |
| 18·776 | 19·267 | 19·74 | 20·24 | 20·77 | 21·30 | 22·40 | 23·50 |
| 24·871 | 25·525 | 26·20 | 33·90 | 34·65 | 35·40 | 36·90 | 38·45 |
| 30·884 | 31·702 | 32·50 | 33·32 | 34·15 | 35·00 | 36·75 | 28·50 |
| 36·816 | 37·798 | 38·80 | 39·85 | 41·10 | 42·20 | 44·67 | 47·17 |
| 42·665 | 43·811 | 45·00 | 46·03 | 47·15 | 48·30 | 50·70 | 53·15 |
| 48·433 | 49·742 | 51·25 | 52·78 | 55·00 | 56·50 | 58·00 | 60·50 |

nesses are printed in dark figures.
plying the tabular weight of a like wrought-iron tube by 1·021.

## TABLE 106.—FERRULES FOR BOILER TUBES, IRON AND STEEL.

(Howell & Co.)

| External Diameter at Larger End. | Thickness by B. W. G. | | Length. | External Diameter at Larger End. | Thickness by B. W. G. | | Length. |
|---|---|---|---|---|---|---|---|
| | Iron. | Steel. | | | Iron. | Steel. | |
| Inches. | No. | No. | Inches. | Inches. | No. | No. | Inches. |
| $1\frac{1}{2}$ | 14 | 15 | 1 | $2\frac{7}{8}$ | 10 | 11 | $1\frac{1}{4}$ |
| $1\frac{5}{8}$ | 13 | 14 | $1\frac{1}{8}$ | 3 | 10 | 11 | $1\frac{1}{4}$ |
| $1\frac{3}{4}$ | 12 | 13 | $1\frac{3}{16}$ | $3\frac{1}{8}$ | 10 | 11 | $1\frac{5}{16}$ |
| $1\frac{7}{8}$ | 12 | 13 | $1\frac{3}{16}$ | $3\frac{1}{4}$ | 10 | 11 | $1\frac{5}{16}$ |
| 2 | 12 | 13 | $1\frac{3}{16}$ | $3\frac{3}{8}$ | 9 | 10 | $1\frac{5}{16}$ |
| $2\frac{1}{8}$ | 11 | 12 | $1\frac{3}{16}$ | $3\frac{1}{2}$ | 9 | 10 | $1\frac{5}{16}$ |
| $2\frac{1}{4}$ | 11 | 12 | $1\frac{3}{16}$ | $3\frac{5}{8}$ | 9 | 10 | $1\frac{3}{8}$ |
| $2\frac{3}{8}$ | 11 | 12 | $1\frac{3}{16}$ | $3\frac{3}{4}$ | 8 | 9 | $1\frac{3}{8}$ |
| $2\frac{1}{2}$ | 11 | 12 | $1\frac{1}{4}$ | $3\frac{7}{8}$ | 8 | 9 | $1\frac{3}{8}$ |
| $2\frac{5}{8}$ | 11 | 12 | $1\frac{1}{4}$ | 4 | 8 | 9 | $1\frac{3}{8}$ |
| $2\frac{3}{4}$ | 11 | 12 | $1\frac{1}{4}$ | | | | |

## TABLE 107.—LAP-WELDED SEMI-STEEL LOCOMOTIVE TUBES: SIZES AND WEIGHT. Standard Dimensions. (National Tube Works Company, U.S.A.).

(Haswell.)

| Diameter. | | Thickness. | Wire Gauge. | Circumference. | | Transverse Areas. | | | Length per Sq. Foot of Surface. | | Weight per Foot. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| External | Internal. | | | External. | Internal. | External. | Internal. | Metal. | External. | Internal. | |
| Ins. | Ins. | Ins. | No. | Ins. | Ins. | Sq.Ins. | Sq.Ins. | Sq.Ins. | Feet. | Feet. | Lbs. |
| 1 | ·834 | ·083 | 14 | 3·142 | 2·62 | ·785 | ·546 | ·239 | 3·82 | 4·58 | ·81 |
| 1·25 | 1·084 | ·083 | 14 | 3·927 | 3·405 | 1·227 | ·923 | ·304 | 3·056 | 3·524 | 1·03 |
| 1·5 | 1·31 | ·095 | 13 | 4·712 | 4·115 | 1·767 | 1·348 | ·419 | 2·546 | 2·916 | 1·42 |
| 1·75 | 1·532 | ·109 | 12 | 5·498 | 4·813 | 2·405 | 1·843 | ·562 | 2·183 | 2·493 | 1·91 |
| 2 | 1·782 | ·109 | 12 | 6·283 | 5·598 | 3·142 | 2·494 | ·648 | 1·91 | 2·144 | 2·2 |
| 2·25 | 2·032 | ·109 | 12 | 7·069 | 6·384 | 3·976 | 3·243 | ·733 | 1·698 | 1·88 | 2·49 |
| 2·5 | 2·26 | ·12 | 11 | 7·854 | 7·1 | 4·909 | 4·011 | ·898 | 1·528 | 1·69 | 3·05 |
| 2·75 | 2·51 | ·12 | 11 | 8·639 | 7·885 | 5·94 | 4·948 | ·992 | 1·389 | 1·522 | 3·37 |
| 3 | 2·76 | ·12 | 11 | 9·425 | 8·67 | 7·069 | 5·983 | 1·086 | 1·273 | 1·384 | 3·68 |

TABLE 108.—LAP-WELDED CHARCOAL IRON BOILER TUBES (National Tube Works Company, U.S.A.). Standard Dimensions.

(Haswell.)

| Diameter. | | Thickness. | Wire Gauge. | Circumference. | | Transverse Areas. | | | Length per Sq. Foot of Surface. | | Weight per Foot. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| External. | Internal. | | | Ext'rnal | Internal. | External. | Internal. | Metal | External. | Internal. | |
| Ins. | Ins. | Ins. | No. | Ins. | Ins. | Sq.Ins. | Sq.Ins. | S.Ins. | Feet. | Feet. | Lbs. |
| 1 | ·86 | ·072 | 15 | 3·14 | 2·69 | ·78 | ·57 | ·21 | 3·82 | 4·46 | ·71 |
| 1·125 | ·98 | ·072 | 15 | 3·53 | 3·08 | ·99 | ·76 | ·24 | 3·39 | 3·89 | ·8 |
| 1·25 | 1·11 | ·072 | 15 | 3·93 | 3·47 | 1·23 | ·96 | ·27 | 3·06 | 3·45 | ·89 |
| 1·32 | 1·15 | ·083 | 14 | 4·12 | 3·6 | 1·35 | 1·03 | ·32 | 2·91 | 3·33 | 1·08 |
| 1·375 | 1·21 | ·083 | 14 | 4·32 | 3·8 | 1·48 | 1·15 | ·34 | 2·78 | 3·16 | 1·13 |
| 1·5 | 1·33 | ·083 | 14 | 4·71 | 4·19 | 1·77 | 1·4 | ·37 | 2·55 | 2·86 | 1·24 |
| 1·625 | 1·43 | ·095 | 13 | 5·1 | 4·51 | 2·07 | 1·62 | ·46 | 2·35 | 2·66 | 1·53 |
| 1·75 | 1·56 | ·095 | 13 | 5·5 | 4·9 | 2·4 | 1·91 | ·49 | 2·18 | 2·45 | 1·66 |
| 1·875 | 1·68 | ·095 | 13 | 5·89 | 5·29 | 2·76 | 2·23 | ·53 | 2·04 | 2·27 | 1·78 |
| 2 | 1·81 | ·095 | 13 | 6·28 | 5·69 | 3·14 | 2·57 | ·57 | 1·91 | 2·11 | 1·91 |
| 2·125 | 1·93 | ·095 | 13 | 6·68 | 6·08 | 3·55 | 2·94 | ·61 | 1·8 | 1·97 | 2·04 |
| 2·25 | 2·06 | ·095 | 13 | 7·07 | 6·47 | 3·98 | 3·33 | ·64 | 1·7 | 1·85 | 2·16 |
| 2·375 | 2·16 | ·109 | 12 | 7·46 | 6·78 | 4·43 | 3·65 | ·78 | 1·61 | 1·77 | 2·61 |
| 2·5 | 2·28 | ·109 | 12 | 7·85 | 7·17 | 4·91 | 4·09 | ·82 | 1·53 | 1·67 | 2·75 |
| 2·75 | 2·53 | ·109 | 12 | 8·64 | 7·95 | 5·94 | 5·03 | ·9 | 1·39 | 1·51 | 3·04 |
| 2·875 | 2·66 | ·109 | 12 | 9·03 | 8·35 | 6·49 | 5·54 | ·95 | 1·33 | 1·44 | 3·18 |
| 3 | 2·78 | ·109 | 12 | 9·42 | 8·74 | 7·07 | 6·08 | ·99 | 1·27 | 1·37 | 3·33 |
| 3·25 | 3·01 | ·12 | 11 | 10·21 | 9·46 | 8·3 | 7·12 | 1·18 | 1·17 | 1·26 | 3·96 |
| 3·5 | 3·26 | ·12 | 11 | 11 | 10·24 | 9·62 | 8·35 | 1·27 | 1·09 | 1·17 | 4·28 |
| 3·75 | 3·51 | ·12 | 11 | 11·78 | 11·03 | 11·04 | 9·68 | 1·37 | 1·02 | 1·09 | 4·6 |
| 4 | 3·73 | ·134 | 10 | 12·57 | 11·72 | 12·57 | 10·94 | 1·63 | ·95 | 1·02 | 5·47 |
| 4·25 | 3·98 | ·134 | 10 | 13·35 | 12·51 | 14·19 | 12·45 | 1·73 | ·9 | ·96 | 5·82 |
| 4·5 | 4·23 | ·134 | 10 | 14·14 | 13·29 | 15·9 | 14·07 | 1·84 | ·85 | ·9 | 6·17 |
| 4·75 | 4·48 | ·134 | 10 | 14·92 | 14·08 | 17·72 | 15·78 | 1·94 | ·8 | ·85 | 6·53 |
| 5 | 4·7 | ·148 | 9 | 15·71 | 14·78 | 19·63 | 17·38 | 2·26 | ·76 | ·81 | 7·58 |
| 5·25 | 4·95 | ·148 | 9 | 16·49 | 15·56 | 21·65 | 19·27 | 2·37 | ·73 | ·77 | 7·97 |
| 5·5 | 5·2 | ·148 | 9 | 17·28 | 16·35 | 23·76 | 21·27 | 2·49 | ·7 | ·73 | 8·36 |
| 6 | 5·67 | ·165 | 8 | 18·85 | 17·81 | 28·27 | 25·25 | 3·02 | ·64 | ·67 | 10·16 |
| 7 | 6·67 | ·165 | 8 | 21·99 | 20·95 | 38·48 | 34·94 | 3·54 | ·55 | ·57 | 11·9 |
| 8 | 7·64 | ·165 | 8 | 25·13 | 24·1 | 50·27 | 46·2 | 4·06 | ·48 | ·50 | 13·65 |
| 9 | 8·59 | ·18 | 7 | 28·27 | 27·14 | 63·62 | 58·63 | 4·99 | ·42 | ·44 | 16·76 |
| 10 | 9·59 | ·203 | 6 | 31·42 | 30·14 | 78·54 | 72·29 | 6·25 | ·38 | ·4 | 20·99 |
| 11 | 10·56 | ·22 | 5 | 34·56 | 33·17 | 95·03 | 87·58 | 7·45 | ·35 | ·36 | 25·03 |
| 12 | 11·54 | ·229 | 4·5 | 37·7 | 36·26 | 113·1 | 104·63 | 8·47 | ·32 | ·33 | 28·46 |
| 13 | 12·52 | ·238 | 4 | 40·84 | 39·34 | 132·73 | 123·19 | 9·54 | ·29 | ·3 | 32·06 |
| 14 | 13·5 | ·248 | 3·5 | 43·98 | 42·42 | 153·94 | 143·22 | 10·71 | ·27 | ·28 | 36 |
| 15 | 14·48 | ·259 | 3 | 47·12 | 45·5 | 176·71 | 164·72 | 11·99 | ·25 | ·26 | 40·3 |
| 16 | 15·43 | ·284 | 2 | 50·26 | 48·48 | 201·06 | 187·04 | 14·02 | ·24 | ·25 | 47·11 |
| 17 | 16·4 | ·3 | 1 | 53·41 | 51·52 | 226·98 | 211·24 | 15·74 | ·22 | ·23 | 52·89 |
| 18 | 17·32 | ·34 | 0 | 56·55 | 54·41 | 254·47 | 235·61 | 18·86 | ·21 | ·22 | 63·32 |

NOTE.—In estimating effective heating or evaporating surface of Tubes, as heating liquids by steam, superheating steam, or transferring heat from one liquid or one gas to another, mean surface of Tubes is to be computed.

**TABLE 109.—LAP-WELDED WROUGHT-IRON TUBES FOR ARTESIAN WELLS: WEIGHT PER LINEAL FOOT.**

(Lloyd and Lloyd.)

SWELLED JOINTS: Screwed together, External and Internal Screws.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| External Diameter, inches | 2 | 2¼ | 2½ | 2¾ | 3 | 3¼ | 3½ | 3¾ | 4 | 4¼ | Inches. |
| Thickness, I. W. G., No. | 11 | 11 | 11 | 11 | 11 | 10 | 10 | 10 | 9 | 9 | Thickness. |
| Weight per lineal foot, lbs. | 2·347 | 2·659 | 2·971 | 3·283 | 3·596 | 4·344 | 4·693 | 5·041 | 5·932 | 6·316 | Weight. |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| External Diameter, inches | 4½ | 4¾ | 5 | 5¼ | 5½ | 5¾ | 6 | 6½ | 7 | Inches. |
| Thickness, I. W. G., No. | 9 | 8 | 8 | 8 | 7 | 7 | 7 | 7 | 7 | Thickness. |
| Weight per lineal foot, lbs. | 6·701 | 7·871 | 8·300 | 8·729 | 9·963 | 10·480 | 10·900 | 11·836 | 12·773 | Weight. |

FLUSH JOINTS: Screwed together, External and Internal Screws.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| External Diameter, inches | 2 | 2¼ | 2½ | 2¾ | 3 | 3¼ | 3½ | 3¾ | 4 | 4¼ | Inches. |
| Weight in pounds per lineal foot: ¼ inch thick | 4·552 | 5·202 | 5·852 | 6·503 | 7·153 | 7·803 | 8·453 | 9·104 | 9·754 | 10·404 | Weight. |
| $\frac{5}{16}$ „ „ | 5·480 | 6·291 | 7·103 | 7·914 | 8·726 | 9·537 | 10·349 | 11·160 | 11·972 | 12·784 | „ |
| ⅜ „ „ | 6·340 | 7·315 | 8·291 | 9·266 | 10·242 | 11·217 | 12·193 | 13·168 | 14·444 | 15·119 | „ |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| External Diameter, inches | 4½ | 4¾ | 5 | 5¾ | 5½ | 5¼ | 6 | 6½ | 7 | Inches. |
| Weight in pounds per lineal foot: ¼ inch thick | 11·054 | 11·705 | 12·355 | 13·006 | 13·656 | 14·306 | 14·957 | 16·533 | 17·558 | Weight. |
| $\frac{5}{16}$ „ „ | 13·598 | 14·407 | 15·219 | 16·030 | 16·843 | 17·653 | 18·465 | 20·088 | 21·711 | „ |
| ⅜ „ „ | 16·096 | 17·070 | 18·046 | 19·021 | 19·997 | 20·972 | 21·948 | 23·898 | 25·850 | „ |

TABLE 110.—LAP-WELDED IRON PIPES OR TUBES OF LARGE DIAMETER: WEIGHT OF 1 LINEAL FOOT.

(Lloyd and Lloyd.)

| Internal Diameter, inches | | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Weight in pounds per lineal foot | $\frac{1}{4}$ inch thick | 22 | 25 | 28 | 30 | 33 | 35 | 38 | 41 | 43 | 46 | 48 |
| | $\frac{3}{8}$ ,, ,, | 35 | 38 | 42 | 46 | 50 | 54 | 58 | 62 | 66 | 70 | 74 |
| | $\frac{1}{2}$ ,, ,, | 47 | 52 | 58 | 63 | 68 | 73 | 78 | 84 | 89 | 94 | 100 |

| Internal Diameter, inches | | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Weight in pounds per lineal foot | $\frac{1}{4}$ inch thick | 51 | 54 | 56 | 59 | 62 | 64 | 67 | 69 | 72 | 75 |
| | $\frac{3}{8}$ ,, ,, | 78 | 82 | 86 | 90 | 93 | 97 | 101 | 105 | 109 | 113 |
| | $\frac{1}{2}$ ,, ,, | 105 | 110 | 115 | 120 | 126 | 131 | 136 | 141 | 147 | 152 |

| Internal Diameter, inches | | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Weight in pounds per lineal foot | $\frac{1}{4}$ inch thick | 77 | 80 | 83 | 85 | 88 | 90 | 93 | 96 | 98 | 101 |
| | $\frac{3}{8}$ ,, ,, | 117 | 121 | 125 | 129 | 133 | 137 | 140 | 144 | 148 | 152 |
| | $\frac{1}{2}$ ,, ,, | 157 | 162 | 168 | 173 | 178 | 183 | 188 | 194 | 199 | 204 |

| Internal Diameter, inches | | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Weight in pounds per lineal foot | $\frac{1}{4}$ inch thick | 104 | 106 | 109 | 111 | 114 | 117 | 119 | 122 | 124 | 127 |
| | $\frac{3}{8}$ ,, ,, | 156 | 160 | 164 | 168 | 172 | 176 | 180 | 184 | 188 | 192 |
| | $\frac{1}{2}$ ,, ,, | 210 | 215 | 220 | 225 | 230 | 236 | 241 | 246 | 251 | 257 |

Steam-tubes, gas-tubes, and water-tubes, are made to weight, according to the "size" or bore; butt-welded. The weight of tubes of any given size varies very much with different manufacturers. Table 111 gives the average weights of gas-tubes, as made by seven leading manufacturers. "Steam-tubes" and "water-tubes" are made to the same sizes as the gas-tubes, but of different weights. The tubes are proved by hydrostatic pressure, usually according to the following scale:—

| | |
|---|---|
| Gas-tubes . . . . | 50 lbs. per square inch. |
| Water-tubes . . . . | 300 lbs. " " |
| Steam-tubes . . . | 500 lbs. " " |

To find the thickness of a pipe, when the inside or the outside diameter, and the weight per lineal foot, are given.

Let $d$ be the internal diameter, inches, D the external diameter, $w$ the weight of pipe in pounds per lineal foot. Let, also, $c$ be a constant of weight for the same material, say, the weight of a straight bar 1 inch square, 1 foot long, in pounds. Then,

1*st*. *When the internal diameter is given*,

$$\text{The external diameter, } D = \sqrt{\frac{w}{\cdot 7854\, c} + d^2} \quad . \quad . \qquad (1)$$

2*nd*. *When the external diameter is given*,

$$\text{The internal diameter, } d = \sqrt{D^2 - \frac{w}{\cdot 7854\, c}} \quad . \quad . \qquad (2)$$

The other diameter having been ascertained by one or other of these formulas, half the difference of the external and internal diameters, is the thickness of the pipe.

For example, a lead pipe of 1 inch bore, weighs 70 pounds for a 15-feet length. What is the thickness? The weight $w$, per lineal foot is $\left(\frac{70}{15} =\right)$ 4·666 pounds; the weight $c$ of a 1-inch square bar, 1 foot long, is 4·944 pounds; and by formula (1), the external diameter D is equal to $\sqrt{\frac{4{\cdot}666}{{\cdot}7854 \times 4{\cdot}944} \times 1^2} = \sqrt{1{\cdot}202 + 1} = \sqrt{2{\cdot}202} = 1{\cdot}484$ inches. Then $1{\cdot}484 - 1 = {\cdot}484$ inch, one half of which is ·242 inch, nearly ¼ inch, the thickness of the lead pipe.

Conversely, taking the same pipe for example, let the external diameter, 1·484, be given, to find the internal diameter. By formula (2), the internal diameter, $d$, is equal to

$$\sqrt{1{\cdot}484^2 - \frac{4{\cdot}666}{{\cdot}7854 \times 4{\cdot}944}} = \sqrt{2{\cdot}202 - 1{\cdot}202} = \sqrt{1} = 1 \text{ inch}$$

bore.

The constants for other metals are given in TABLE 89, page 221.

TABLE 111.—BUTT-WELDED GAS TUBES AND FITTINGS: AVERAGE WEIGHT.

| Tubes. | | | Fittings. | | |
|---|---|---|---|---|---|
| Bore. | Weight per 100 Feet. | Length to weigh One Ton. | Weight of Ten Elbows. | Weight of Ten Tees. | Weight of Ten Crosses. |
| Inches. | Pounds. | Feet. | Lb. Oz. | Lb. Oz. | Lb. Oz. |
| $\frac{1}{8}$ | 26·3 | 8502 | 1 1 | 1 0 | 1 8 |
| $\frac{1}{4}$ | 40·5 | 5532 | 1 7 | 1 8 | 1 14 |
| $\frac{3}{8}$ | 57·5 | 3892 | 1 13 | 2 4 | 2 3 |
| $\frac{1}{2}$ | 82·9 | 2700 | 2 15 | 3 0 | 3 4 |
| $\frac{3}{4}$ | 122·0 | 1836 | 4 6 | 5 4 | 5 11 |
| 1 | 174·9 | 1281 | 6 4 | 7 10 | 9 2 |
| $1\frac{1}{4}$ | 244·3 | 917 | 10 10 | 12 15 | 14 11 |
| $1\frac{1}{2}$ | 310·2 | 722 | 15 8 | 16 7 | 18 10 |
| $1\frac{3}{4}$ | 359·5 | 623 | 15 12 | 20 0 | 21 4 |
| 2 | 421·0 | 532 | 22 6 | 27 0 | 31 4 |
| $2\frac{1}{4}$ | 515·0 | 435 | 30 2 | 32 8 | 41 4 |
| $2\frac{1}{2}$ | 610·4 | 367 | 46 2 | 50 15 | 51 4 |
| $2\frac{3}{4}$ | 658·8 | 340 | 55 10 | 68 8 | 80 10 |
| 3 | 759·3 | 295 | 73 8 | 85 5 | 88 12 |
| $3\frac{1}{2}$ | 878·4 | 255 | 101 0 | 121 0 | 129 0 |
| 4 | 1032·3 | 217 | 126 0 | 144 0 | 158 0 |

*Note* 1.—Normal length, 14 feet.

*Note* 2.—Steam tubes and water tubes also are manufactured of the same bores.

TABLE 112.—STANDARD SIZES OF CONNECTING PIPES OR UNIONS OF GAS METERS.
(Board of Trade, Standards Department.)

| Size of Meter. | Boss. Mean Diameter of External Screw. | Boss. Number of Threads per Inch. | Boss. Internal Diameter. | Cap. Mean Diameter of Internal Screw. | Cap. Number of Threads per Inch. | Cap. Height of Cap. | Lining. External Diameter to enter Boss. |
|---|---|---|---|---|---|---|---|
| Lights. | Inches. | Threads. | Inches. | Inches. | Threads. | Inches. | Inches. |
| 150 | 3·68 | 9 | 3·05 | 3·65 | 9 | 1·20 | 3·03 |
| 100 } 80 } | 3·00 | 11 | 2·30 | 2·95 | 11 | 1·00 | 2·28 |
| 60 | 2·45 | 11 | 2·00 | 2·40 | 11 | ·80 | 1·98 |
| 50 | 2·25 | 11 | 1·80 | 2·25 | 11 | ·70 | 1·75 |
| 30 | 2·05 | 11 | 1·55 | 2·00 | 11 | ·70 | 1·53 |
| 20 | 1·80 | 11 | 1·42 | 1·75 | 11 | ·60 | 1·40 |
| 10 | 1·45 | 11 | 1·05 | 1·40 | 11 | ·60 | 1·03 |
| 5 | 1·15 | 14 | ·83 | 1·10 | 14 | ·50 | ·81 |
| 3 | ·98 | 19 | ·67 | ·94 | 19 | ·50 | ·65 |
| 2 } 1 } | ·88 | 19 | ·57 | ·84 | 19 | ·40 | ·55 |
| 0 | ·70 | 19 | ·50 | ·66 | 19 | ·40 | ·50 |

TABLE 113.—IRON WELDED STEAM, GAS, AND WATER PIPES (National Tube Works Company).
(Haswell.)

| Internal Diameter. | Thickness. | Weight per Lineal Foot. | Internal Diameter. | Thickness. | Weight per Lineal Foot. |
|---|---|---|---|---|---|
| Inches. | Inch. | Pounds. | Inches. | Inch. | Pounds. |
| $\frac{1}{4}$ | ·07 | ·24 | 5 | ·26 | 14·50 |
| $\frac{1}{2}$ | ·09 | ·42 | 6 | ·28 | 18·76 |
| $\frac{3}{8}$ | ·09 | ·56 | 7 | ·30 | 23·27 |
| $\frac{1}{2}$ | ·11 | ·84 | 8 | ·32 | 28·18 |
| $\frac{3}{4}$ | ·11 | 1·11 | 9 | ·34 | 33·70 |
| 1 | ·13 | 1·67 | 10 | ·37 | 40·06 |
| $1\frac{1}{4}$ | ·14 | 2·24 | 11 | ·37 | 45·02 |
| $1\frac{1}{2}$ | ·14 | 2·68 | 12 | ·37 | 48·98 |
| 2 | ·15 | 3·61 | 13 | ·37 | 53·92 |
| $2\frac{1}{2}$ | ·20 | 5·74 | 14 | ·37 | 57·89 |
| 3 | ·22 | 7·50 | 15 | ·28 | 47·11 |
| $3\frac{1}{2}$ | ·23 | 9·00 | 16 | ·30 | 52·89 |
| 4 | ·24 | 10·66 | 17 | ·34 | 63·32 |
| $4\frac{1}{2}$ | ·25 | 12·34 | | | |

TABLE 114.—COLD DRAWN STEEL TUBES: DIMENSIONS.
(Howell & Co.)

| External Diameter. | Thickness in Fractions of an Inch. | | | | | | | | | Thickness according to the Birmingham Wire Gauge. | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Inches. | Inch. | Inch. | Inch. | Inch. | Inch. | Inch. | Inch. | Inch. | Inch. | W.G. | W.G. | W.G. No. 15 | W.G. No. 14 | W.G. No. 13 | W.G. No. 12 | W.G. No. 11 | W.G. No. 10 |
| ½ | 1/16 | 3/32 | 1/8 | ... | ... | ... | ... | ... | ... | ... | .. | | | | | | |
| ⅝ | ,, | ,, | ,, | 3/16 | ... | ... | ... | ... | ... | ... | No. 16 | ,, | ,, | ,, | ,, | ,, | ,, |
| ¾ | ,, | ,, | ,, | ,, | 1/4 | ... | ... | ... | ... | ... | ,, | ,, | ,, | ,, | ,, | ,, | ,, |
| ⅞ | ,, | ,, | ,, | ,, | ,, | ... | ... | ... | ... | ... | ,, | ,, | ,, | ,, | ,, | ,, | ,, |
| 1 | ,, | ,, | ,, | ,, | ,, | ... | ... | ... | ... | No. 18 | ,, | ,, | ,, | ,, | ,, | ,, | ,, |
| 1⅛ | ,, | ,, | ,, | ,, | ,, | 5/16 | ... | ... | ... | ,, | ,, | ,, | ,, | ,, | ,, | ,, | ,, |
| 1¼ | ,, | ,, | ,, | ,, | ,, | ,, | 3/8 | ... | ... | ,, | ,, | ,, | ,, | ,, | ,, | ,, | ,, |
| 1⅜ | ,, | ,, | ,, | ,, | ,, | ,, | ,, | 7/16 | ... | ,, | ,, | ,, | ,, | ,, | ,, | ,, | ,, |
| 1½ | ,, | ,, | ,, | ,, | ,, | ,, | ,, | ,, | 1/2 | ... | ,, | ,, | ,, | ,, | ,, | ,, | ,, |
| 1⅝ | ,, | ,, | ,, | ,, | ,, | ,, | ,, | ,, | ,, | ... | ,, | ,, | ,, | ,, | ,, | ,, | ,, |
| 1¾ | ,, | ,, | ,, | ,, | ,, | ,, | ,, | ,, | ,, | ... | ,, | ,, | ,, | ,, | ,, | ,, | ,, |
| 1⅞ | ,, | ,, | ,, | ,, | ,, | ,, | ,, | ,, | ,, | ... | ,, | ,, | ,, | ,, | ,, | ,, | ,, |
| 2 | ,, | ,, | ,, | ,, | ,, | ,, | ,, | ,, | ,, | ... | ,, | ,, | ,, | ,, | ,, | ,, | ,, |
| 2⅛ | ... | ,, | ,, | ,, | ,, | ,, | ,, | ,, | ,, | ... | ... | ,, | ,, | ,, | ,, | ,, | ,, |
| 2¼ | ... | ,, | ,, | ,, | ,, | ,, | ,, | ,, | ,, | ... | ... | ,, | ,, | ,, | ,, | ,, | ,, |
| 2⅜ | ... | ,, | ,, | ,, | ,, | ,, | ,, | ,, | ,, | ... | ... | ... | ,, | ,, | ,, | ,, | ,, |
| 2½ | ... | ,, | ,, | ,, | ,, | ,, | ,, | ,, | ,, | ... | ... | ... | ,, | ,, | ,, | ,, | ,, |
| 2⅝ | ... | ,, | ,, | ,, | ,, | ,, | ,, | ,, | ,, | ... | ... | ... | ,, | ,, | ,, | ,, | ,, |
| 2¾ | ... | ,, | ,, | ,, | ,, | ,, | ,, | ,, | ,, | ... | ... | ... | ,, | ,, | ,, | ,, | ,, |
| 2⅞ | ... | ,, | ,, | ,, | ,, | ,, | ,, | ,, | ,, | ... | ... | ... | ... | ,, | ,, | ,, | ,, |
| 3 | ... | ,, | ,, | ,, | ,, | ,, | ,, | ,, | ,, | ... | ... | ... | ... | ,, | ,, | ,, | ,, |
| 3⅛ | ... | ,, | ,, | ,, | ,, | ,, | ,, | ,, | ,, | ... | ... | ... | ... | ... | ... | ... | ... |
| 3¼ | ... | ,, | ,, | ,, | ,, | ,, | ,, | ,, | ,, | ... | ... | ... | ... | ... | ... | ... | ... |
| 3⅜ | ... | ,, | ,, | ,, | ,, | ,, | ,, | ,, | ,, | ... | ... | ... | ... | ... | ... | ... | ... |
| 3½ | ... | ,, | ,, | ,, | ,, | ,, | ,, | ,, | ,, | ... | ... | ... | ... | ... | ... | ... | ... |

*Note.*—Normal length, 20 feet.

## STEEL PIPES.

### Mild Steel Pipes.

The Steel Pipe Company show, in the annexed Tables, the relative thickness and weight of pipes of cast-iron, wrought-iron, and steel, for equal strengths :—

TABLE 115.—RELATIVE THICKNESS OF RIVETED PIPES FOR EQUAL STRENGTH.

| Metal. | Cast-Iron. | Wrought-Iron. | Steel. |
|---|---|---|---|
| Weight of 1 square foot, 1 inch thick . . . . . . | 37·5 lbs. | 40 lbs. | 40·8 lbs. |
| Tenacity per square inch . . | 18,000 lbs. | 48,600 lbs. | 72,000 lbs. |
| Relative strength for equal thicknesses . . . . . | 1 | 2·7 | 4 |
| Factor of safety . . . . . | 10 | 6 | 5 |
| Relative strength due to factor of safety . . . . . | 1 | 4·5 | 8 |
| Reduction in strength due to riveted joints . . . . . | ... | 30 per cent. | 30 per cent. |
| Relative strength after reduction for riveted joints . . | 1 | 3·15 | 5·6 |
| Relative thickness for plates of equal strength . . . . | 1 | ·3174 | ·1786 |

TABLE 116.—RELATIVE WEIGHT OF PIPES FOR EQUAL STRENGTH.

| Metal. | Cast-Iron. | Wrought-Iron. | Steel. |
|---|---|---|---|
| Thickness of plates, weighing 40 lb. per square foot . . | 1·066 inches. | 1·00 inch. | ·9804 inch. |
| Relative strength for equal weight . . . . . . | 1 | 2·533 | 3·678 |
| Relative strength due to factor of safety . . . . . | 1 | 4·22 | 7·356 |
| Relative strength after reduction for riveted joints . . | 1 | 2·955 | 5·149 |
| Relative weight of plain cylinders of equal strength . . | 1 | ·3384 | ·1942 |
| Increase in weight of pipes due to socket and spigot joints . | 5·8 per cent. | 15 per cent. | 15 per cent. |
| Relative weight of pipes of equal strength . . . | 1 | ·3678 | ·2111 |

From the first Table it appears that the resistance of riveted steel pipes to bursting is 5·6 times that of cast-iron pipes of equal thickness. The longitudinal seams of the

riveted pipes are double-riveted and are estimated to have 70 per cent. of the strength of the solid undrilled plates. The pipes are united in lengths of from 4 feet to 6 feet, with circular seams of single riveting.

The minimum thickness of welded plates is $\frac{1}{8}$ inch.

The weight of steel pipes, complete with sockets, spigots, rivets, lap-joints, and asphalte coating $\frac{1}{32}$ inch thick, is one-fourth of that of cast-iron pipes of equal strength. The coating effectually prevents corrosion. The weight of steel pipes complete as above specified, is given by the formula (1).

*Weight of Steel Pipes per Lineal Foot.*

$$W = \cdot 33\, d\, w \qquad (1)$$

W = weight per lineal foot.
$d$ = diameter in inches.
$w$ = weight of plate or sheet in pounds per square foot.
$t$ = thickness of pipe in inches.
H = working head in feet of water.

*Thickness of Pipes and Working Head of Pressure.*

Cast-iron pipes
$$t = \cdot 00012\, d\, H \qquad (2)$$
$$H = \frac{t}{\cdot 00012\, d} \qquad (3)$$

Steel pipes
$$t = \cdot 000025\, d\, H \qquad (4)$$
$$H = \frac{t}{\cdot 000025\, d} \qquad (5)$$

A 12-inch riveted steel pipe, 8 feet 7 inches long, $\frac{1}{8}$ inch thick, was tested under a bursting pressure of 760 lbs. per square inch. It leaked slightly at one of the rivets, and a portion of the caulking slightly yielded. No other sign of damage was visible. The longitudinal lap-joints had $1\frac{3}{8}$ inches of lap, with $\frac{1}{4}$-inch rivets at $1\frac{1}{8}$ inches of pitch. It was fitted at each end with a circular flange $2\frac{1}{2}$ inches by $2\frac{1}{2}$ inches by $\frac{1}{4}$-inch thick. The ultimate tensile strength of the metal was 24 tons per square inch. The stress on the metal was at the rate of $760 \times 12 = 9120$ lbs. per lineal inch, or $(9120 \times 4 = )$ 36480 lbs., or 16·3 tons per square inch of section of both sides together. This is about equal to 70 per cent. of the ultimate resistance, or 16·8 tons per square inch, the strength at the joint; showing that the calculated ultimate resistance is corroborated by the results of the test.

## TABLE 117.—WEIGHT OF RIVETED STEEL PIPES, WITH PLAIN ENDS.

(The Steel Pipe Company).

| Thickness. Inches. | ·064 | ·072 | ·080 | ·092 | ·104 | ·116 | ·125 | ·128 | ·144 | ·160 | ·176 | ·1875 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Imperial Gauge. | 16 | 15 | 14 | 13 | 12 | 11 | $\frac{1}{8}$ | 10 | 9 | 8 | 7 | $\frac{3}{16}$ |
| Diam. | Weight per Lineal Foot. | | | | | | | | | | | |
| Ins. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. |
| 3 | 2·75 | 3·20 | 3·50 | 4·05 | | | | | | | | |
| 4 | 3·54 | 4·04 | 4·44 | 5·13 | | | | | | | | |
| 5 | 4·33 | 4·89 | 5·38 | 6·21 | | | | | | | | |
| 6 | 5·12 | 5·73 | 6·32 | 7·29 | 8·35 | 9·42 | | | | | | |
| 7 | 5·91 | 6·58 | 7·26 | 8·37 | 9·57 | 10·78 | | | | | | |
| 8 | 6·70 | 7·43 | 8·20 | 9·45 | 10·79 | 12·14 | | | | | | |
| 9 | 7·49 | 8·29 | 9·14 | 10·53 | 12·91 | 13·50 | 14·48 | | | | | |
| 10 | 8·28 | 9·12 | 10·08 | 11·61 | 14·13 | 14·86 | 15·95 | | | | | |
| 11 | ... | 9·96 | 11·02 | 12·69 | 15·35 | 16·22 | 17·42 | | | | | |
| 12 | ... | 10·86 | 11·96 | 13·77 | 16·57 | 17·58 | 18·89 | 19·41 | 22·42 | 24·94 | 27·71 | 29·83 |
| 13 | ... | ... | 12·90 | 14·85 | 17·79 | 18·94 | 20·36 | 20·91 | 24·10 | 26·80 | 29·76 | 32·01 |
| 14 | ... | ... | 13·84 | 15·93 | 19·01 | 20·30 | 21·83 | 22·42 | 25·77 | 28·67 | 31·81 | 34·20 |
| 15 | ... | ... | ... | 17·01 | 20·23 | 21·67 | 23·30 | 23·92 | 27·44 | 30·53 | 33·86 | 36·37 |
| 16 | ... | ... | ... | 18·10 | 21·45 | 23·03 | 24·77 | 25·43 | 29·12 | 32·40 | 35·91 | 38·56 |
| 17 | ... | ... | ... | ... | 22·67 | 24·40 | 26·24 | 26·94 | 30·80 | 34·26 | 37·96 | 40·74 |
| 18 | ... | ... | ... | ... | 23·89 | 25·75 | 27·71 | 28·44 | 32·47 | 36·13 | 40·01 | 42·93 |
| 19 | ... | ... | ... | ... | ... | 27·11 | 29·18 | 29·95 | 34·15 | 38·00 | 42·06 | 45·11 |
| 20 | ... | ... | ... | ... | ... | 28·47 | 30·65 | 31·45 | 35·82 | 39·85 | 44·11 | 47·30 |
| 21 | ... | ... | .. | ... | ... | ... | 32·12 | 32·96 | 37·50 | 41·71 | 46·16 | 49·48 |
| 22 | ... | ... | .. | ... | ... | ... | 33·59 | 34·47 | 39·18 | 43·58 | 48·21 | 51·67 |
| 23 | ... | ... | ... | ... | ... | ... | 35·06 | 35·97 | 40·85 | 45·44 | 50·26 | 53·85 |
| 24 | ... | ... | ... | ... | ... | ... | 36·53 | 37·48 | 42·53 | 47·31 | 52·31 | 56·04 |
| 25 | ... | ... | ... | ... | ... | ... | ... | 38·98 | 44·20 | 49·17 | 54·36 | 58·22 |
| 26 | ... | ... | ... | ... | ... | ... | ... | 40·50 | 45·88 | 51·04 | 56·41 | 60·41 |
| 27 | ... | ... | ... | ... | ... | ... | ... | 42·00 | 47·56 | 52·90 | 58·46 | 62·60 |
| 28 | ... | ... | ... | ... | ... | ... | ... | 43·50 | 49·23 | 54·77 | 60·51 | 64·78 |
| 29 | ... | ... | ... | ... | ... | ... | ... | 45·00 | 50·91 | 56·63 | 62·56 | 66·96 |
| 30 | ... | ... | ... | ... | ... | ... | ... | 46·50 | 52·58 | 58·50 | 64·61 | 69·15 |

*Note.*—Usual lengths, 18 feet to 40 feet.

TABLE 118.—WEIGHT OF RIVETED STEEL PIPES, WITH PLAIN ENDS: TO 36 INCHES IN DIAMETER.

(The Steel Pipe Company.)

| Thickness. Inches. | $\frac{1}{8}$ | $\frac{3}{16}$ | $\frac{1}{4}$ | $\frac{5}{16}$ | $\frac{3}{8}$ | $\frac{7}{16}$ | $\frac{1}{2}$ | $\frac{9}{16}$ | $\frac{5}{8}$ | $\frac{11}{16}$ | $\frac{3}{4}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Diam. | WEIGHT PER LINEAL FOOT. | | | | | | | | | | |
| Ins. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. |
| 12 | 18·9 | 29·8 | 40·5 | | | | | | | | |
| 13 | 20·3 | 32·0 | 43·3 | | | | | | | | |
| 14 | 21·8 | 34·2 | 46·2 | | | | | | | | |
| 15 | 23·3 | 36·4 | 49·0 | 60·3 | | | | | | | |
| 16 | 24·7 | 38·5 | 51·8 | 63·9 | | | | | | | |
| 17 | 26·2 | 40·7 | 54·7 | 67·5 | | | | | | | |
| 18 | 27·7 | 42·9 | 57·5 | 71·0 | 85·7 | | | | | | |
| 19 | 29·2 | 45·1 | 60·4 | 74·6 | 90·0 | | | | | | |
| 20 | 30·6 | 47·3 | 63·2 | 78·3 | 94·3 | | | | | | |
| 21 | 32·1 | 49·5 | 66·1 | 81·8 | 98·6 | 112·5 | | | | | |
| 22 | 33·6 | 51·6 | 68·9 | 85·4 | 102·9 | 117·6 | | | | | |
| 23 | 35·0 | 53·8 | 71·8 | 89·0 | 107·2 | 122·8 | | | | | |
| 24 | 36·5 | 56·0 | 74·6 | 92·6 | 111·5 | 127·9 | 149·0 | 167·8 | 186·7 | 205·9 | 225·6 |
| 25 | ... | 58·2 | 77·5 | 96·2 | 115·8 | 133·1 | 154·7 | 174·2 | 193·8 | 213·6 | 234·0 |
| 26 | ... | 60·4 | 80·3 | 99·8 | 120·1 | 138·2 | 160·4 | 180·6 | 200·9 | 221·4 | 242·4 |
| 27 | ... | 62·6 | 83·1 | 103·4 | 124·4 | 143·4 | 166·1 | 187·0 | 208·0 | 229·2 | 250·8 |
| 28 | ... | 64·8 | 86·0 | 107·0 | 128·7 | 148·5 | 171·8 | 193·4 | 215·1 | 237·0 | 259·3 |
| 29 | ... | 66·9 | 88·8 | 110·6 | 133·0 | 153·7 | 177·5 | 199·8 | 222·2 | 244·8 | 267·7 |
| 30 | ... | 69·1 | 91·7 | 114·2 | 137·3 | 158·8 | 183·2 | 206·2 | 229·3 | 252·5 | 276·1 |
| 31 | ... | ... | 94·5 | 117·8 | 141·6 | 164·0 | 188·9 | 212·7 | 236·4 | 260·3 | 284·5 |
| 32 | ... | ... | 97·4 | 121·4 | 145·9 | 169·2 | 194·6 | 219·1 | 243·5 | 268·1 | 293·0 |
| 33 | ... | ... | 100·2 | 125·0 | 150·2 | 174·3 | 200·3 | 225·5 | 250·6 | 275·9 | 301·4 |
| 34 | ... | ... | 103·0 | 128·6 | 154·5 | 179·5 | 206·0 | 232·0 | 257·8 | 283·7 | 309·8 |
| 35 | ... | ... | 105·9 | 132·2 | 158·8 | 184·6 | 211·7 | 238·3 | 264·9 | 291·4 | 318·2 |
| 36 | ... | ... | 108·7 | 135·8 | 163·1 | 189·8 | 217·4 | 244·7 | 272·0 | 299·2 | 326·7 |

The usual lengths to which the riveted steel pipes are constructed, are from 18 feet to 40 feet.

The longitudinal seams of riveted steel pipes, double-riveted, are proved to have a bursting strength equal to 70 per cent. of that of the solid undrilled plates.

### TABLE 119.—WEIGHT OF RIVETED STEEL PIPES, WITH PLAIN ENDS: TO 60 INCHES IN DIAMETER.

(The Steel Pipe Company.)

| Thickness. Inches. | 1/4 | 5/16 | 3/8 | 7/16 | 1/2 | 9/16 | 5/8 | 11/16 | 3/4 | 7/8 | 1 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Diam. | WEIGHT PER LINEAL FOOT. | | | | | | | | | | |
| Ins. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. |
| 37 | 111·5 | 139·0 | 167·0 | 195·0 | 223·0 | 251·0 | 279·0 | 307·0 | 343·5 | | |
| 38 | 114·0 | 143·0 | 171·5 | 200·0 | 229·0 | 257·5 | 286·0 | 315·0 | 352·0 | | |
| 39 | 117·0 | 146·5 | 176·0 | 205·0 | 234·5 | 264·0 | 293·0 | 322·5 | 360·0 | | |
| 40 | 120·0 | 150·0 | 180·0 | 210·0 | 240·0 | 270·0 | 300·0 | 330·0 | 370·0 | | |
| 41 | 122·5 | 153·5 | 184·0 | 215·0 | 246·0 | 277·0 | 308·0 | 339·0 | 380·0 | | |
| 42 | 125·0 | 157·0 | 188·5 | 220·0 | 252·0 | 284·0 | 316·0 | 348·0 | 390·0 | | |
| 43 | 127·5 | 160·5 | 193·0 | 225·5 | 258·0 | 291·0 | 324·0 | 356·5 | 399·5 | | |
| 44 | 130·0 | 164·0 | 197·0 | 230·5 | 264·0 | 298·0 | 332·0 | 365·5 | 409·5 | 460·0 | |
| 45 | 132·5 | 167·5 | 201·5 | 236·0 | 270·5 | 305·0 | 340·0 | 374·5 | 419·0 | 472·0 | |
| 46 | 135·0 | 171·0 | 205·5 | 241·0 | 276·5 | 312·0 | 348·0 | 383·0 | 429·0 | 484·5 | |
| 47 | 137·5 | 174·5 | 210·0 | 246·0 | 282·5 | 319·0 | 356·0 | 392·0 | 439·0 | 496·5 | |
| 48 | 140·0 | 178·0 | 214·5 | 251·5 | 289·0 | 326·0 | 364·0 | 401·0 | 449·0 | 509·0 | 576·0 |
| 49 | ... | 181·5 | 218·5 | 256·5 | 295·0 | 333·0 | 372·0 | 410·0 | 459·0 | 521·0 | 591·0 |
| 50 | ... | 185·0 | 223·0 | 262·0 | 301·0 | 340·0 | 380·0 | 419·0 | 469·0 | 533·5 | 606·0 |
| 51 | ... | 188·5 | 227·0 | 267·0 | 307·0 | 347·0 | 388·0 | 428·0 | 479·0 | 545·5 | 621·0 |
| 52 | ... | 192·0 | 231·5 | 272·0 | 313·0 | 354·0 | 396·0 | 437·0 | 489·0 | 558·0 | 636·0 |
| 53 | ... | 195·5 | 236·0 | 277·5 | 319·0 | 361·0 | 404·0 | 446·0 | 498·5 | 570·0 | 651·0 |
| 54 | ... | 199·0 | 240·0 | 282·5 | 325·0 | 368·0 | 412·0 | 454·5 | 508·5 | 582·5 | 666·0 |
| 55 | ... | ... | 244·5 | 288·0 | 331·5 | 375·0 | 420·0 | 463·5 | 518·0 | 594·5 | 681·0 |
| 56 | ... | ... | 248·5 | 293·0 | 337·5 | 382·0 | 428·0 | 472·0 | 528·0 | 607·0 | 696·0 |
| 57 | ... | ... | 253·0 | 298·0 | 343·5 | 389·0 | 436·0 | 481·0 | 538·0 | 619·0 | 711·0 |
| 58 | ... | ... | 257·5 | 303·5 | 350·0 | 396·0 | 444·0 | 490·0 | 548·0 | 631·5 | 726·0 |
| 59 | ... | ... | 261·5 | 308·5 | 356·0 | 403·0 | 452·0 | 499·0 | 558·0 | 643·5 | 741·0 |
| 60 | ... | ... | 266·0 | 314·0 | 362·0 | 410·0 | 460·0 | 508·0 | 568·0 | 656·0 | 756·0 |

The usual lengths to which the riveted steel pipes are constructed, are from 18 feet to 40 feet.

The longitudinal seams, double-riveted, have 70 per cent. of the strength of the solid plate.

## TABLE 120.—WEIGHT OF LAP-WELDED PIPES WITH PLAIN ENDS.

(The Steel Pipe Company.)

| Thickness. Inches. | ·176 | ·192 | ·212 | ·232 | ·252 | ·276 | ·300 | ·25 | ·3125 | ·375 | ·4375 | ·500 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Imperial Gauge. | 7 | 6 | 5 | 4 | 3 | 2 | 1 | $\frac{1}{4}$ | $\frac{5}{15}$ | $\frac{3}{8}$ | $\frac{7}{16}$ | $\frac{1}{2}$ |
| Diam. | WEIGHT PER LINEAL FOOT. | | | | | | | | | | | |
| Ins. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. |
| 3 | 5·97 | 6·54 | 7·27 | 8·00 | 8·75 | 9·65 | 10·57 | 8·69 | 11·04 | 13·53 | 15·19 | 18·70 |
| 4 | 7·85 | 8·59 | 9·54 | 10·48 | 11·44 | 12·60 | 13·78 | 11·36 | 14·38 | 17·53 | 20·76 | 24·04 |
| 5 | 9·73 | 10·64 | 11·80 | 12·95 | 14·13 | 15·55 | 16·98 | 14·03 | 17·70 | 21·53 | 25·43 | 29·38 |
| 6 | 11·61 | 12·69 | 14·07 | 15·43 | 16·82 | 18·50 | 20·18 | 16·70 | 21·06 | 25·54 | 30·10 | 34·72 |
| 7 | 13·49 | 14·73 | 16·33 | 17·91 | 19·51 | 21·44 | 23·40 | 19·37 | 24·40 | 29·54 | 34·77 | 40·06 |
| 8 | 15·37 | 16·79 | 18·60 | 20·38 | 22·20 | 24·40 | 26·60 | 22·04 | 27·74 | 33·55 | 39·44 | 45·40 |
| 9 | 17·25 | 18·83 | 20·87 | 22·86 | 24·90 | 27·34 | 29·80 | 24·71 | 31·08 | 37·55 | 44·11 | 50·74 |
| 10 | 19·13 | 20·89 | 23·13 | 25·33 | 27·40 | 30·28 | 33·00 | 27·38 | 34·42 | 41·56 | 48·78 | 56·08 |
| 11 | 21·01 | 22·94 | 25·40 | 27·81 | 30·28 | 33·23 | 36·21 | 30·05 | 37·76 | 45·56 | 53·45 | 61·42 |
| 12 | 22·89 | 24·98 | 27·66 | 30·29 | 32·97 | 36·18 | 39·41 | 32·72 | 41·10 | 49·57 | 58·12 | 66·76 |
| 13 | 24·77 | 27·03 | 29·92 | 32·76 | 35·66 | 39·13 | 42·62 | 35·39 | 44·43 | 53·57 | 62·79 | 72·10 |
| 14 | 26·65 | 29·08 | 32·19 | 35·24 | 38·33 | 42·07 | 45·82 | 38·06 | 47·77 | 57·58 | 67·46 | 77·43 |
| 15 | 28·53 | 31·12 | 34·45 | 37·72 | 41·04 | 45·02 | 49·03 | 40·73 | 51·11 | 61·58 | 72·13 | 82·77 |
| 16 | 30·41 | 33·18 | 36·72 | 40·19 | 43·74 | 47·97 | 52·23 | 43·40 | 54·45 | 65·59 | 76·80 | 88·11 |
| 17 | 33·29 | 35·23 | 38·98 | 42·67 | 46·43 | 50·92 | 55·44 | 46·07 | 57·78 | 69·59 | 81·47 | 93·45 |
| 18 | 34·17 | 37·28 | 41·24 | 45·15 | 49·12 | 53·86 | 58·64 | 48·74 | 61·12 | 73·60 | 86·14 | 98·80 |
| 19 | 36·05 | 39·33 | 43·51 | 47·62 | 51·81 | 56·81 | 61·84 | 51·40 | 64·46 | 77·60 | 90·81 | 104·13 |
| 20 | 37·93 | 41·38 | 45·77 | 50·10 | 54·50 | 59·76 | 65·05 | 54·07 | 67·80 | 81·60 | 95·48 | 109·47 |
| 21 | 39·81 | 43·43 | 48·04 | 52·58 | 57·20 | 62·70 | 68·25 | 56·74 | 71·13 | 85·61 | 100·15 | 114·81 |
| 22 | 41·69 | 45·47 | 50·30 | 55·05 | 59·88 | 65·65 | 71·46 | 59·41 | 74·47 | 89·62 | 104·82 | 120·15 |
| 23 | 43·57 | 47·52 | 52·57 | 57·53 | 62·57 | 68·60 | 74·66 | 62·08 | 77·81 | 93·62 | 109·49 | 125·45 |
| 24 | 45·45 | 49·57 | 54·83 | 60·01 | 65·27 | 71·55 | 77·87 | 64·75 | 81·15 | 97·63 | 114·16 | 130·82 |
| 25 | 47·33 | 51·62 | 57·09 | 62·48 | 67·96 | 74·50 | 81·08 | 67·42 | 84·48 | 101·63 | 118·83 | 136·16 |
| 26 | 49·21 | 53·67 | 59·36 | 64·96 | 70·65 | 77·44 | 84·28 | 70·10 | 87·82 | 105·64 | 123·50 | 141·50 |
| 27 | 51·09 | 55·72 | 61·63 | 67·43 | 73·34 | 80·39 | 87·49 | 72·76 | 91·16 | 109·64 | 128·17 | 146·81 |
| 28 | 52·97 | 57·77 | 63·89 | 69·91 | 76·03 | 83·34 | 90·72 | 75·44 | 94·50 | 113·65 | 132·84 | 152·18 |
| 29 | 54·85 | 59·82 | 66·16 | 72·39 | 78·72 | 86·28 | 93·92 | 78·11 | 97·83 | 117·65 | 137·51 | 157·52 |
| 30 | 56·73 | 61·87 | 68·42 | 74·86 | 81·42 | 89·23 | 97·13 | 80·78 | 101·17 | 121·66 | 142·18 | 162·86 |

Usual length, 14 feet to 18 feet.

TABLE 121.—ROLLED IRON JOISTS: ESTIMATED

(Measures

Factor of

| Reference Number. | Clear Span in Feet, or | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 |
| No. | Tons. | Tons. | Tons. | Tons. | Tons. | Tons. | Tons. | Tons. |
| 1 | 90·0 | 67·4 | 54·0 | 45·0 | 38·6 | 33·7 | 30·0 | 27·0 |
| 2 | 66·6 | 50·0 | 40·0 | 33·3 | 28·7 | 25·0 | 22·2 | 20·0 |
| 3 | 61·8 | 46·2 | 36·6 | 30·9 | 26·5 | 23·1 | 20·6 | 18·3 |
| 4 | 50·8 | 37·9 | 30·4 | 25·4 | 21·7 | 19·0 | 16·9 | 15·2 |
| 5 | ... | 43·6 | 35·0 | 29·0 | 25·0 | 21·8 | 19·2 | 17·3 |
| 6 | 45·5 | 32·8 | 26·8 | 21·9 | 18·7 | 16·4 | 14·8 | 13·1 |
| 7 | 36·2 | 27·2 | 21·7 | 18·1 | 15·5 | 13·6 | 12·1 | 10·9 |
| 8 | 33·3 | 25·0 | 20·0 | 16·6 | 14·2 | 12·5 | 11·1 | 10·0 |
| 9 | 24·7 | 18·5 | 14·8 | 12·4 | 10·6 | 9·3 | 8·2 | 7·4 |
| 10 | 21·6 | 16·2 | 13·0 | 10·8 | 9·3 | 8·1 | 7·2 | 6·5 |
| 11 | ... | ... | ... | ... | ... | ... | ... | ... |
| 12 | 19·2 | 14·5 | 11·6 | 9·6 | 8·3 | 7·2 | 6·4 | 5·8 |
| 13 | ... | 15·6 | 12·5 | 10·4 | 8·9 | 7·8 | 7·0 | 6·2 |
| 14 | 18·6 | 14·0 | 11·2 | 9·3 | 8·0 | 7·0 | 6·2 | 5·6 |
| 15 | 13·9 | 10·5 | 8·0 | 7·0 | 6·0 | 5·2 | 4·5 | 4·2 |
| 16 | 15·4 | 11·5 | 9·2 | 7·7 | 6·6 | 5·8 | 5·1 | 4·6 |
| 17 | 13·1 | 9·8 | 7·8 | 6·5 | 5·6 | 4·9 | 4·3 | 4·0 |
| 18 | 9·3 | 7·0 | 5·3 | 4·7 | 4·0 | 3·5 | 3·1 | 2·8 |
| 19 | 6·4 | 4·8 | 3·9 | 3·2 | 2·8 | 2·4 | 2·1 | 1·9 |
| 20 | 11·5 | 8·5 | 6·8 | 5·7 | 4·9 | 4·3 | 3·8 | 3·4 |
| 21 | 7·6 | 5·7 | 4·4 | 3·8 | 3·2 | 2·8 | 2·5 | 2·3 |
| 22 | 4·1 | 3·8 | 2·5 | 2·1 | 1·8 | 1·5 | 1·4 | 1·2 |
| 23 | 3·1 | 2·3 | 1·9 | 1·6 | 1·3 | 1·2 | 1·0 | 0·9 |
| 24 | 1·9 | 1·3 | 1·1 | 0·9 | 0·8 | 0·7 | 0·6 | 0·5 |
| 25 | 5·5 | 4·2 | 3·3 | 2·8 | 2·4 | 2·1 | 1·8 | 1·6 |
| 26 | 4·1 | 3·0 | 2·4 | 2·1 | 1·7 | 1·5 | 1·4 | 1·2 |
| 27 | 2·3 | 1·7 | 1·4 | 1·1 | 0·9 | 0·8 | 0·7 | 0·67 |
| 28 | 1·7 | 1·3 | 1·0 | 0·9 | 0·7 | 0·6 | 0·57 | 0·50 |
| 29 | 0·8 | 0·6 | 0·5 | 0·4$\frac{1}{7}$ | 0·3$\frac{4}{7}$ | 0·3 | 0·28 | 0·25 |

*Note.*—For Dimensions and

SAFE PERMANENT DISTRIBUTED LOADS.

Brothers & Co.).

Safety, 1-4th.

| Distance between Supports. | | | | | | | | Reference Number. |
|---|---|---|---|---|---|---|---|---|
| 22 | 24 | 26 | 28 | 30 | 32 | 34 | 36 | |
| Tons. | Tons. | Tons. | Tons. | Tons. | Tons. | Tons. | Tons. | No. |
| 24·5 | 22·5 | 20·8 | 19·3 | 18·0 | 16·8 | 15·9 | 15·0 | 1 |
| 18·0 | 16·7 | 15·6 | 14·4 | 13·3 | 12·5 | 11·8 | 11·1 | 2 |
| 16·8 | 15·4 | 14·2 | 13·2 | 12·3 | 11·6 | 10·9 | 10·3 | 3 |
| 13·8 | 12·7 | 11·7 | 10·9 | 10·1 | 9·5 | 9·0 | 8·4 | 4 |
| 15·7 | 14·2 | 13·2 | 12·2 | 11·0 | 10·2 | 9·8 | ... | 5 |
| 11·9 | 10·9 | 10·1 | 9·4 | 8·7 | 8·5 | 7·7 | 7·2 | 6 |
| 9·9 | 9·0 | 8·4 | 7·8 | 7·2 | 6·8 | 6·4 | 6·0 | 7 |
| 9·0 | 8·3 | 7·7 | 7·0 | 6·7 | 6·2 | 5·8 | 5·5 | 8 |
| 6·7 | 6·2 | 5·7 | 5·3 | 4·9 | 4·6 | 4·3 | 4·1 | 9 |
| 5·9 | 5·4 | 5·0 | 4·6 | 4·3 | 4·0 | 3·8 | 3·6 | 10 |
| ... | ... | ... | ... | ... | ... | ... | ... | 11 |
| 5·3 | 4·8 | 4·4 | 4·1 | 3·9 | ... | ... | ... | 12 |
| 5·6 | 5·0 | 4·6 | 4·2 | ... | ... | ... | ... | 13 |
| 5·1 | 4·6 | 4·3 | 4·0 | 3·7 | ... | ... | ... | 14 |
| 3·8 | 3·5 | 3·2 | 3·0 | 2·8 | ... | ... | ... | 15 |
| 4·2 | 3·8 | 3·6 | 3·3 | 3·1 | 2·9 | 2·7 | ... | 16 |
| 3·6 | 3·3 | 3·0 | 2·8 | 2·6 | ... | ... | ... | 17 |
| 2·5 | 2·3 | 2·2 | 2·0 | 1·9 | ... | ... | ... | 18 |
| 1·8 | 1·6 | 1·5 | 1·4 | 1·2 | ... | ... | ... | 19 |
| 3·1 | 2·8 | 2·6 | 2·4 | 2·1 | ... | ... | ... | 20 |
| 2·0 | 1·9 | 1·7 | 1·5 | 1·3 | ... | ... | ... | 21 |
| 1·1 | 1·0 | 0·9 | 0·8 | 0·7 | ... | ... | ... | 22 |
| ... | ... | ... | ... | ... | ... | ... | ... | 23 |
| ... | ... | ... | ... | ... | ... | ... | ... | 24 |
| 1·5 | 1·4 | 1·3 | 1·2 | 1·1 | ... | ... | ... | 25 |
| 1·1 | 1·0 | 0·9 | 0·8 | 0·7 | ... | ... | ... | 26 |
| 0·60 | 0·58 | 0·52 | ... | ... | ... | ... | ... | 27 |
| 0·41½ | 0·40 | 0·38 | ... | ... | ... | ... | ... | 28 |
| 0·22 | 0·20 | 0·18 | ... | ... | ... | ... | ... | 29 |

Weights of Joists, see Table 122.

## Table 122.—Rolled Iron Joists.

(Measures Brothers & Co.)

| Reference Number. | Sectional Dimensions. Depth × Width. | Thickness of Web. | Thickness of Flanges (average). | Weight per Lineal Foot. | Stock Lengths. |
|---|---|---|---|---|---|
| | Inches. | Inch. | Inch. | Pounds. | Feet. |
| 1 | $19\frac{3}{4} \times 7\frac{1}{8}$ | $\frac{13}{16}$ *b* | $1\frac{1}{16}$ | 100 | 16 to 40 |
| 2 | $17\frac{3}{4} \times 6\frac{3}{4}$ | $\frac{11}{16}$ | $\frac{15}{16}$ | 82 | 16 to 40 |
| 3 | $16 \times 6$ | $\frac{9}{16}$ | $\frac{13}{16}$ | 62 | 8 to 40 |
| 4 | $14 \times 6$ | $\frac{9}{16}$ $\frac{1}{32}$ | $\frac{13}{16}$ | 60 | 8 to 40 |
| 5 | $12 \times 7\frac{1}{4}$ | ... | ... | 72 | 16 to 35 |
| 6 | $12 \times 6$ | $\frac{5}{8}$ $\frac{1}{32}$ | $\frac{3}{4}$ | 56 | 6 to 40 |
| 7 | $12 \times 5$ | $\frac{1}{2}$ $\frac{1}{32}$ | $\frac{5}{8}$ $\frac{1}{32}$ | 42 | 6 to 40 |
| 8 | $10 \times 6$ | $\frac{1}{2}$ | $\frac{7}{8}$ | 56 | 7 to 36 |
| 9 | $10 \times 5$ | $\frac{7}{16}$ | $\frac{11}{16}$ | 36 | 6 to 40 |
| 10 | $10 \times 4\frac{1}{2}$ | $\frac{7}{16}$ | $\frac{9}{16}$ | 32 | 6 to 30 |
| 11 | $8\frac{7}{8} \times 6$ | ... | ... | 42 | 10 to 30 |
| 12 | $9\frac{1}{2} \times 4\frac{1}{2}$ | $\frac{3}{8}$ $\frac{1}{32}$ | $\frac{9}{16}$ | 29 | 6 to 40 |
| 13 | $9\frac{1}{4} \times 3\frac{3}{4}$ | $\frac{3}{8}$ $\frac{1}{32}$ | $\frac{3}{8}$ $\frac{1}{32}$ | 24 | 6 to 40 |
| 14 | $8 \times 6$ | $\frac{1}{2}$ $\frac{1}{32}$ | $\frac{1}{2}$ | 34 | 6 to 30 |
| 15 | $8 \times 5$ | $\frac{3}{8}$ $\frac{1}{32}$ | $\frac{1}{2}$ $\frac{1}{32}$ | 29 | 5 to 40 |
| 16 | $8 \times 4$ | $\frac{1}{2}$ | $\frac{7}{16}$ | 22 | 5 to 30 |
| 17 | $7 \times 3\frac{3}{4}$ | $\frac{5}{16}$ | $\frac{7}{16}$ | 20 | 5 to 40 |
| 18 | $6 \times 5$ | $\frac{1}{2}$ | $\frac{1}{2}$ | 29 | 5 to 36 |
| 19 | $6\frac{1}{4} \times 3\frac{1}{8}$ | $\frac{5}{16}$ | $\frac{7}{16}$ | 16 | 5 to 40 |
| 20 | $5 \times 4\frac{1}{2}$ | $\frac{5}{16}$ $\frac{1}{32}$ | $\frac{1}{2}$ | 23 | 5 to 36 |
| 21 | $4\frac{3}{4} \times 3$ | $\frac{5}{16}$ | $\frac{5}{16}$ | 13 | 5 to 36 |
| 22 | $4 \times 3$ | $\frac{1}{4}$ $\frac{1}{32}$ | $\frac{5}{16}$ | 12 | 5 to 30 |
| 23 | $3 \times 3$ | $\frac{3}{16}$ $\frac{1}{32}$ | $\frac{5}{16}$ *b* | 10 | 5 to 30 |
| 24 | $8 \times 2\frac{1}{2}$ | $\frac{5}{16}$ $\frac{1}{32}$ | $\frac{3}{8}$ $\frac{1}{32}$ | 15 | 6 to 30 |
| 25 | $7 \times 2\frac{1}{4}$ | $\frac{5}{16}$ | $\frac{3}{8}$ $\frac{1}{32}$ | 14 | 6 to 30 |
| 26 | $6\frac{1}{4} \times 2$ | $\frac{1}{4}$ *f* | $\frac{3}{8}$ | 11 | 5 to 30 |
| 27 | $4\frac{3}{4} \times 1\frac{3}{4}$ | $\frac{3}{16}$ *f* | $\frac{5}{16}$ | 8 | 5 to 26 |
| 28 | $4 \times 1\frac{3}{4}$ | $\frac{3}{16}$ *f* | $\frac{5}{16}$ | 7 | 5 to 26 |
| 29 | $3 \times 1\frac{1}{2}$ | $\frac{3}{16}$ | $\frac{3}{16}$ $\frac{1}{32}$ | 5 | 5 to 26 |

*b* = bare ; *f* = full.

*Note.*—For Safe Loads, see Table 121.

## Table 123.—Rolled Iron Joists: Calculated Breaking Load at the Centre.

(Butterley Iron Company.)

| Sectional Dimensions. Depth × Width. | Minimum Thickness of Web. | Average Thickness of Flanges. | Weight per Lineal Foot. | Coefficient of Transverse Strength: Loaded at the Middle. |
|---|---|---|---|---|
| Inches | Inch. | Inch. | Pounds. | |
| 20 × 10 | 13/16 | 1 1/4 | 140 to 144 | 20,312 |
| 19 3/4 × 6 1/4 | 5/8 | 3/4 | 69 to 70 | 8,700 |
| 18 × 6 1/4 | 5/8 | 3/4 | 67 to 70 | 7,704 |
| 16 × 6 1/4 | 5/8 | 3/4 | 63 to 66 | 6,696 |
| 16 × 5 1/2 | 11/16 | 1 | 69 to 72 | 7,644 |
| 15 × 5 1/2 | 5/8 | 7/8 | 57 to 60 | 6,704 |
| 14 × 6 1/4 | 5/8 | 3/4 | 59 to 62 | 5,544 |
| 12 × 6 1/4 | 5/8 | 3/4 | 59 to 62 | 5,064 |
| 12 × 6 | 3/4 | 1 | 67 to 77 | 6,048 |
| 12 × 5 | 1/2 | 13/16 | 46 to 50 | 4,069 |
| 10 1/2 × 5 1/2 | 1/2 | 5/8 | 38 to 41 | 2,700 |
| 10 × 5 | 1/2 | 5/8 | 36 to 40 | 2,564 |
| 9 × 5 1/2 | 1/2 | 3/4 | 42 to 45 | 2,902 |
| 9 × 4 1/2 | 1/2 | 5/8 | 33 to 37 | 2,144 |
| 8 1/2 × 4 | 9/16 | 3/4 | 33 to 36 | 2,100 |
| 8 × 4 1/2 | 1/2 | 9/16 | 28 to 30 | 1,748 |
| 8 × 4 | 13/16 | 7/8 | 40 to 42 | 2,340 |
| 8 × 2 1/2 | 7/16 | 5/8 | 19 to 21 | 1,194 |
| 7 1/4 × 2 1/4 | 1/2 | 7/16 | 19 to 21 | 807 |
| 7 × 3 1/2 | 1/2 | 9/16 | 23 to 25 | 1,144 |
| 6 3/8 × 3 3/8 | 7/16 | 7/16 | 18 to 20 | 846 |
| 6 1/4 × 2 7/8 | 7/16 | 1/2 | 18 to 20 | 825 |
| 6 × 6 | 1/2 | 9/16 | 30 to 32 | 1,512 |
| 6 × 5 | 7/16 | 9/16 | 26 to 28 | 1,245 |
| 6 × 4 | 1/2 | 9/16 | 23 to 25 | 1,094 |
| 5 7/8 × 5 | 1/2 | 1/2 | 27 to 29 | 1,117 |
| 5 1/2 × 1 3/4 | 3/8 | 1/2 | 11 to 13 | 375 |
| 5 × 1 3/4 | 5/16 | 1/2 | 9 to 11 | 334 |
| 4 1/2 × 4 | 3/8 | 3/8 1/32 | 18 to 18 | 560 |
| 4 1/4 × 1 1/2 | 1/4 | 7/16 | 7 to 9 | 251 |
| 3 × 1 1/8 | 5/32 | 1/4 | 3 to 4 | 60 |

*Use of the Table.*—Divide the number in the last column by the span in inches; the quotient is the breaking load in tons at the centre.

*TABLE 124.—ENGLISH
(Dorman, Long

| Number of Section. | Weight per Foot in Pounds. | Normal Sizes in Inches. | Dimensions in Inches. Depth. Width. | Web Thickness. | Mean Th. of Flange. |
|---|---|---|---|---|---|
| No. G 1 | 89 | 20 × $7\frac{1}{2}$ | 20 ×7·5 | ·6 | 1·0 |
| G 2 | 75 | 18 × 7 | 18 ×7· | ·55 | ·94 |
| G 3 | 62 | 16 × 6 | 16 ×6· | ·56 | ·85 |
| G 3A | 50 | 16 × 5 | 16 ×5· | ·51 | ·73 |
| G 4 | 59 | 15 × 6 | 15 ×6· | ·54 | ·85 |
| G 5 | 42 | 15 × 5 | 15 ×5· | ·422 | ·625 |
| G 6 | 57 | 14 × 6 | 14 ×6· | ·51 | ·85 |
| G 6A | 46 | 14 × 6 | 14 ×6· | ·435 | ·65 |
| G 6B | 41·5 | 13 × 5 | 13 ×5· | ·51 | ·6 |
| G 7 | 54 | 12 × 6 | 12 ×6· | ·51 | ·87 |
| G 7B | 44 | 12 × 6 | 12 ×6· | ·41 | ·72 |
| G 7A | 32 | 12 × 5 | 12 ×5· | ·35 | ·56 |
| G 8 | 39 | 12 × 5 | 12 ×5· | ·44 | ·65 |
| G 9 | 45 | 10 × 6 | 10 ×6· | ·489 | ·74 |
| G 10 | 35 | 10 × 5 | 10 ×5· | ·48 | ·6 |
| G 10A | 29 | 10 × 5 | 10 ×5· | ·35 | ·54 |
| G 11 | 30 | 10 × $4\frac{1}{2}$ | 10 ×4·5 | ·387 | ·6 |
| G 11A | 36 | $9\frac{13}{16}$ × $4\frac{1}{2}$ | $9\frac{13}{16}$×4·5 | ·516 | ·69 |
| G 12 | 58 | 9 × 7 | 9 ×7· | ·777 | ·81 |
| G 13 | 20 | 9 × $3\frac{3}{4}$ | 9 ×3·75 | ·3 | ·45 |
| G 14 | 35 | 8 × 6 | 8 ×6· | ·44 | ·61 |
| G 15 | 30 | 8 × 5 | 8 ×5· | ·4 | ·61 |
| G 16 | 25 | 8 × 4 | 8 ×4· | ·41 | ·56 |
| G 16A | 19 | 8 × 4 | 8 ×4· | ·329 | ·4 |
| G 17 | 18 | 7 × $3\frac{3}{4}$ | 7 ×3·75 | ·313 | ·46 |

* For diagrams relating

ROLLED STEEL JOISTS.

& Co., Limited.)

| Square Inches. Area. | Distributed Loads in Tons that One Foot will Carry, being ⅓rd of the Breaking Strain. | ¼th | ⅕th | Number of Section. |
|---|---|---|---|---|
| | | | | No. |
| 26·2 | 1170·91 | 878·18 | 702·54 | G 1 |
| 22·06 | 909·06 | 681·8 | 545·43 | G 2 |
| 18·23 | 642·09 | 481·57 | 385·25 | G 3 |
| 14·7 | 494·67 | 371·01 | 296·80 | G 3A |
| 17·25 | 585·05 | 438·79 | 351·03 | G 4 |
| 12·28 | 393·01 | 294·76 | 235·81 | G 5 |
| 16·71 | 528·91 | 396·38 | 317·34 | G 6 |
| 13·57 | 429·27 | 321·95 | 257·56 | G 6A |
| 12·24 | 328·91 | 246·68 | 197·35 | G 6B |
| 15·9 | 438·41 | 328·8 | 263·04 | G 7 |
| 12·9 | 372·6 | 279·5 | 223·6 | G 7B |
| 9·41 | 261·86 | 196·4 | 157·12 | G 7A |
| 11·41 | 301·60 | 226·2 | 180·96 | G 8 |
| 13·23 | 307·15 | 230·36 | 184·26 | G 9 |
| 10·28 | 227·52 | 170·34 | 136·51 | G 10 |
| 8·53 | 201·48 | 151·11 | 120·89 | G 10A |
| 8·83 | 201·12 | 150·84 | 120·67 | G 11 |
| 10·58 | 224·97 | 168·73 | 134·98 | G 11A |
| 17·05 | 342·61 | 256·96 | 205·56 | G 12 |
| 5·88 | 118·54 | 88·91 | 71·12 | G 13 |
| 10·3 | 198·37 | 148·78 | 119·03 | G 14 |
| 8·81 | 166·86 | 125·14 | 100·11 | G 15 |
| 7·3 | 130·20 | 97·65 | 78·12 | G 16 |
| 5·562 | 100·41 | 75·30 | 60·24 | G 16A |
| 5·28 | 85·31 | 63·98 | 51·18 | G 17 |

to this Table, see p. 270.

TABLE 124.—ENGLISH ROLLED

| Number of Section. | Weight per Foot in Pounds. | Normal Sizes in Inches. | Dimensions in Inches. Depth. Width. | Web Thickness. | Mean Th. of Flange. |
|---|---|---|---|---|---|
| No. G 17A | 16 | 7 × 3¾ | 7 × 3·75 | ·25 | ·375 |
| G 18 | 18 | 6¼ × 3½ | 6¼ × 3·5 | ·339 | ·5 |
| G 19 | 25 | 6 × 5 | 6 × 5· | ·423 | ·52 |
| G 19A | 20 | 6 × 4½ | 6 × 4·5 | ·434 | ·4 |
| G 20 | 16 | 6 × 3 | 6 × 3· | ·39 | ·45 |
| G 20A | 13 | 6 × 3 | 6 × 3· | ·322 | ·35 |
| G 21 | 12 | 6 × 2 | 6 × 2· | ·381 | ·38 |
| G 22 | 10·5 | 5½ × 2 | 5½ × 2· | ·329 | ·38 |
| G 22A | 9 | 5¼ × 1½ | 5¼ × 1·5 | ·368 | ·312 |
| G 23 | 24 | 5 × 5 | 5 × 5· | ·371 | ·56 |
| G 24 | 22 | 5 × 4½ | 5 × 4·5 | ·342 | ·57 |
| G 24A | 19 | 5 × 4 3/16 | 5 × 4·1875 | ·44 | ·45 |
| G 25 | 15 | 5 × 3 | 5 × 3· | ·4 | ·44 |
| G 25A | 11 | 5 × 3 | 5 × 3· | ·23 | ·38 |
| G 26 | 10 | 4¾ × 1¾ | 4¾ × 1·75 | ·4 | ·38 |
| G 26A | 6·5 | 4¾ × 1¾ | 4¾ × 1·75 | ·1875 | ·3125 |
| G 27 | 14 | 4⅝ × 3 | 4⅝ × 3· | ·4 | ·43 |
| G 28 | 12 | 4 × 3 | 4 × 3· | ·299 | ·43 |
| G 28A | 9·5 | 4 × 3 | 4 × 3· | ·225 | ·34 |
| G 29 | 8 | 4 × 1¾ | 4 × 1·75 | ·331 | ·36 |
| G 29A | 5 | 4 × 1¾ | 4 × 1·75 | ·18 | ·24 |
| G 30 | 10·5 | 3½ × 3 | 3½ × 3· | ·35 | ·35 |
| G 31 | 6 | 3½ × 1½ | 3½ × 1·5 | ·296 | ·3 |
| G 32 | 10 | 3 × 3 | 3 × 3· | ·29 | ·38 |
| G 33 | 4 | 3 × 1¼ | 3 × 1·25 | ·218 | ·25 |

STEEL JOISTS (*continued*).

| Square Inches. Area. | Distributed Loads in Tons that One Foot will Carry, being ⅓rd of the Breaking Strain. | ¼th | ⅕th | Number of Section. |
|---|---|---|---|---|
| | | | | No. |
| 4·43 | 73·10 | 54·82 | 43·86 | G 17A |
| 5·28 | 75·29 | 56·47 | 45·17 | G 18 |
| 7·3 | 103·01 | 77·26 | 61·81 | G 19 |
| 5·86 | 79·05 | 59·28 | 47·42 | G 19A |
| 4·693 | 59·59 | 44·69 | 35·75 | G 20 |
| 3·81 | 49·23 | 36·92 | 29·53 | G 20A |
| 3·52 | 39·3 | 29·47 | 23·58 | G 21 |
| 3·08 | 33·35 | 25·01 | 20·01 | G 22 |
| 2·64 | 23·75 | 17·81 | 14·25 | G 22A |
| 7·04 | 84·05 | 63·04 | 50·43 | G 23 |
| 6·45 | 76·62 | 57·47 | 45·97 | G 24 |
| 5·575 | 62·83 | 47·12 | 37·7 | G 24A |
| 4·40 | 45·76 | 34·32 | 27·46 | G 25 |
| 3·25 | 38·32 | 29·12 | 23·29 | G 25A |
| 2·93 | 25·38 | 19·04 | 15·23 | G 26 |
| 1·90 | 19·4 | 14·5 | 11·6 | G 26A |
| 4·10 | 40·49 | 30·37 | 24·29 | G 27 |
| 3·52 | 32·10 | 24·08 | 19·26 | G 28 |
| 2·79 | 26·8 | 20·1 | 16·06 | G 28A |
| 2·347 | 18·34 | 13·76 | 11·0 | G 29 |
| 1·47 | 12·899 | 9·67 | 7·73 | G 29A |
| 3·08 | 23·85 | 17·88 | 14·31 | G 30 |
| 1·76 | 11·82 | 8·86 | 7·09 | G 31 |
| 2·93 | 19·95 | 14·96 | 11·97 | G 32 |
| 1·17 | 6·96 | 5·22 | 4·18 | G 33 |

TABLE 125.—ENGLISH ROLLED STEEL JOISTS:

(Dorman, Long

Factor of

| Reference Number. | Clear Span in Feet | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 16 |
| No. | Tons. | Tons. | Tons. | Tons. | Tons. | Tons. | Tons. | Tons. |
| G 1 | ... | ... | ... | ... | ... | ... | 62 | 54 |
| G 2 | ... | ... | ... | ... | ... | ... | 48 | 42 |
| G 3 | ... | ... | ... | ... | ... | 40 | 34 | 30 |
| G 3A | ... | ... | ... | ... | ... | 30 | 26 | 23 |
| G 4 | ... | ... | ... | ... | 43 | 36 | 31 | 27 |
| G 5 | ... | ... | ... | ... | 29 | 24 | 21 | 18 |
| G 6 | ... | ... | ... | ... | 39 | 33 | 28 | 24 |
| G 6A | ... | ... | ... | ... | 32 | 26 | 22 | 20 |
| G 6B | ... | ... | ... | ... | 24 | 20 | 17 | 15 |
| G 7 | ... | ... | ... | ... | 32 | 27 | 23 | 20 |
| G 7B | ... | ... | ... | ... | 27 | 23 | 20 | 17 |
| G 7A | ... | ... | ... | ... | 19 | 16 | 14 | 12 |
| G 8 | ... | ... | ... | ... | 22 | 18 | 16 | 14 |
| G 9 | ... | ... | ... | 28 | 23 | 19 | 16 | 14 |
| G 10 | ... | ... | ... | 21 | 17 | 14 | 12 | 10 |
| G 10A | ... | ... | ... | 19 | 15 | 12 | 10 | 9 |
| G 11 | ... | ... | ... | 18 | 15 | 12 | 10 | 9 |
| G 11A | ... | ... | ... | 21 | 16 | 14 | 12 | 10 |
| G 12 | ... | ... | ... | 32 | 25 | 21 | 18 | 16 |
| G 13 | ... | ... | ... | 11 | 8 | 7 | 6 | 5 |
| G 14 | ... | ... | 24 | 18 | 14 | 12 | 10 | ... |
| G 15 | ... | ... | 20 | 15 | 12 | 10 | 9 | ... |
| G 16 | ... | ... | 16 | 12 | 9 | 8 | 7 | ... |
| G 16A | ... | ... | 12 | 9 | 7 | 6 | 5 | ... |
| G 17 | ... | 15 | 10 | 7 | 6 | 5 | ... | ... |
| G 17A | ... | 13 | 9 | 6 | 5 | 4 | ... | ... |
| G 18 | ... | 14 | 9 | 7 | 5 | ... | ... | ... |
| G 19 | ... | 19 | 13 | 9 | 7 | ... | ... | ... |
| G 19A | ... | 14 | 9 | 7 | 5 | ... | ... | ... |
| G 20 | ... | 11 | 7 | 5 | 4 | ... | ... | ... |
| G 20A | ... | 9 | 6 | 4 | 3 | ... | ... | ... |
| G 21 | ... | 7 | 4 | 3 | 2 | ... | ... | ... |
| G 22 | ... | 6 | 4 | 3 | 2 | ... | ... | ... |
| G 22A | ... | 4 | 3 | 2 | ... | ... | ... | ... |
| G 23 | ... | 15 | 10 | 7 | ... | ... | ... | ... |
| G 24 | ... | 14 | 9 | 7 | ... | ... | ... | ... |
| G 24A | ... | 11 | 7 | 5 | ... | ... | ... | ... |
| G 25 | ... | 8 | 5 | 4 | ... | ... | ... | ... |
| G 25A | ... | 7 | 4 | 3 | ... | ... | ... | ... |
| G 26 | ... | 4 | 3 | 2 | ... | ... | ... | ... |
| G 26A | ... | 3 | 2 | 1 | ... | ... | ... | ... |
| G 27 | ... | 7 | 5 | 3 | ... | ... | ... | ... |
| G 28 | 12 | 6 | 4 | ... | ... | ... | ... | .. |
| G 29 | 6 | 3 | 2 | ... | ... | ... | ... | ... |
| G 29A | 4 | 2 | 1 | ... | ... | ... | ... | ... |
| G 30 | 8 | 4 | 2 | ... | ... | ... | ... | ... |
| G 31 | 4 | 2 | 1 | ... | ... | ... | ... | ... |
| G 32 | 7 | 3 | ... | ... | ... | ... | ... | ... |
| G 33 | 2 | 1 | ... | ... | ... | ... | ... | ... |

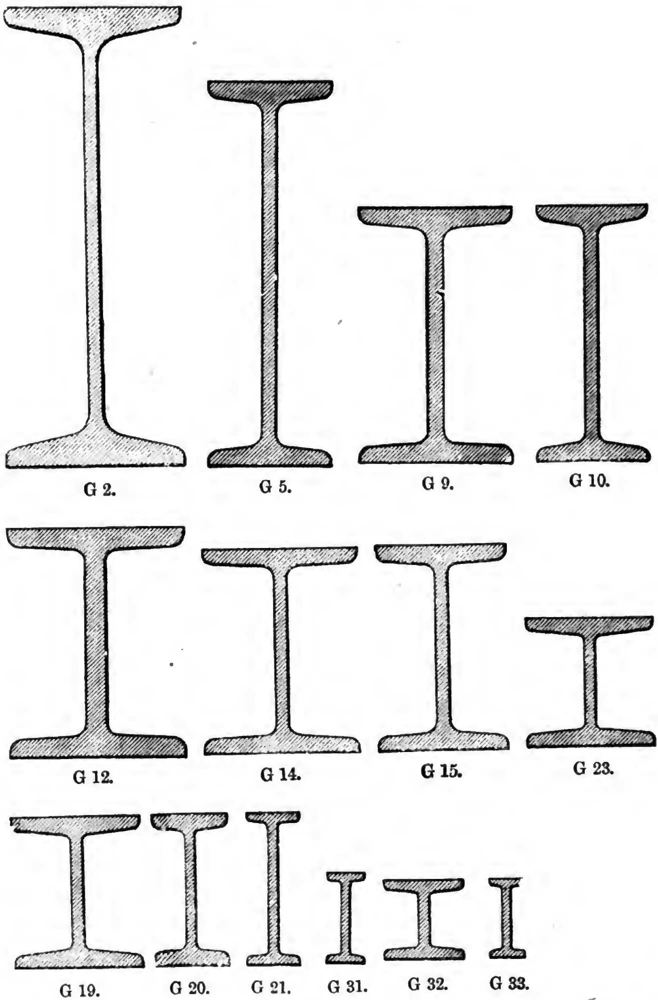
*Note.*—For Dimensions and

## Calculated Safe Permanent Distributed Loads.

& Co., Limited.)

Safety, 1-4th.

| between Supports. | | | | | | | | Reference Number. |
|---|---|---|---|---|---|---|---|---|
| 18 | 20 | 22 | 24 | 26 | 28 | 30 | 32 | |
| Tons. | Tons. | Tons. | Tons. | Tons. | Tons. | Tons. | Tons. | No. |
| 48 | 43 | 39 | 36 | 33 | 21 | 29 | 27 | G 1 |
| 37 | 34 | 30 | 28 | 26 | 24 | 22 | ... | G 2 |
| 26 | 24 | 21 | 20 | 18 | 17 | ... | ... | G 3 |
| 20 | 18 | 16 | 15 | 14 | 13 | ... | ... | G 3A |
| 24 | 21 | 19 | 18 | 16 | ... | ... | ... | G 4 |
| 16 | 14 | 13 | 12 | 11 | ... | ... | ... | G 5 |
| 22 | 19 | 18 | ... | ... | ... | ... | ... | G 6 |
| 17 | 16 | 14 | ... | ... | ... | ... | ... | G 6A |
| 13 | 12 | 11 | ... | ... | ... | ... | ... | G 6B |
| 13 | 16 | ... | ... | ... | ... | ... | ... | G 7 |
| 15 | 14 | ... | ... | ... | ... | ... | ... | G 7B |
| 10 | 9 | ... | ... | ... | ... | ... | ... | G 7A |
| 12 | 11 | ... | ... | ... | ... | ... | ... | G 8 |
| ... | ... | ... | ... | ... | ... | ... | ... | G 9 |
| ... | ... | ... | ... | ... | ... | ... | ... | G 10 |
| ... | ... | ... | ... | ... | ... | ... | ... | G 10A |
| ... | ... | ... | ... | ... | ... | ... | ... | G 11 |
| ... | ... | ... | ... | ... | ... | ... | ... | G 11A |
| ... | ... | ... | ... | ... | ... | ... | ... | G 12 |
| ... | ... | ... | ... | ... | ... | ... | ... | G 13 |
| ... | ... | ... | ... | ... | ... | ... | ... | G 14 |
| ... | ... | ... | ... | ... | ... | ... | ... | G 15 |
| ... | ... | ... | ... | ... | ... | ... | ... | G 16 |
| ... | ... | ... | ... | ... | ... | ... | ... | G 16A |
| ... | ... | ... | ... | ... | ... | ... | ... | G 17 |
| ... | ... | ... | ... | ... | ... | ... | ... | G 17A |
| ... | ... | ... | ... | ... | ... | ... | ... | G 18 |
| ... | ... | ... | ... | ... | ... | ... | ... | G 19 |
| ... | ... | ... | ... | ... | ... | ... | ... | G 19A |
| ... | ... | ... | ... | ... | ... | ... | ... | G 20 |
| ... | ... | ... | ... | ... | ... | ... | ... | G 20A |
| ... | ... | ... | ... | ... | ... | ... | ... | G 21 |
| ... | ... | ... | ... | ... | ... | ... | ... | G 22 |
| ... | ... | ... | ... | ... | ... | ... | ... | G 22A |
| ... | ... | ... | ... | ... | ... | ... | ... | G 23 |
| ... | ... | ... | ... | ... | ... | ... | ... | G 24 |
| ... | ... | ... | ... | ... | ... | ... | ... | G 24A |
| ... | ... | ... | ... | ... | ... | ... | ... | G 25 |
| ... | ... | ... | ... | ... | ... | ... | ... | G 25A |
| ... | ... | ... | ... | ... | ... | ... | ... | G 26 |
| ... | ... | ... | ... | ... | ... | ... | ... | G 26A |
| ... | ... | ... | ... | ... | ... | ... | ... | G 27 |
| ... | ... | ... | ... | ... | ... | ... | ... | G 28 |
| ... | ... | ... | ... | ... | ... | ... | ... | G 29 |
| ... | ... | ... | ... | ... | ... | ... | ... | G 29A |
| ... | ... | ... | ... | ... | ... | ... | ... | G 30 |
| ... | ... | ... | ... | ... | ... | ... | ... | G 31 |
| ... | ... | ... | ... | ... | ... | ... | ... | G 32 |
| ... | ... | ... | ... | ... | ... | ... | ... | G 33 |




...s. 19—32.—Rolled Steel Joists, Table 124 (Dorman, Long & Co.). Scale 1-8th.

## TABLE 125A.—SAFE DISTRIBUTED LOADS IN TONS ON COMPOUND GIRDERS, OF VARYING SPANS.

(Dorman, Long & Co.)

Factor of Safety = 4.

| Number of Section. | Weight per Ft. in Lbs. | Clear Spans in Feet between Supports. | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 24 | 26 | 28 | 30 | 32 | 34 | 36 | 38 |
| G 1 C 1 | 144 | ... | ... | ... | ... | ... | 76 | 69 | 63 | 59 | 54 | 51 | 48 | 45 | 42 | 40 |
| G 1 C 2 | 260 | ... | ... | ... | ... | ... | 132 | 120 | 110 | 102 | 94 | 88 | 83 | 78 | 74 | 69 |
| G 1 C 3 | 377 | ... | ... | ... | ... | ... | 188 | 170 | 157 | 145 | 134 | 125 | 118 | 111 | 104 | 99 |
| G 1 C 4 | 195 | ... | ... | ... | ... | ... | 116 | 106 | 97 | 89 | 83 | 77 | 73 | 68 | 64 | 61 |
| G 1 C 5 | 335 | ... | ... | ... | ... | ... | 191 | 174 | 159 | 147 | 136 | 127 | 119 | 112 | 106 | 100 |
| G 1 C 6 | 480 | ... | ... | ... | ... | ... | 265 | 241 | 221 | 204 | 189 | 176 | 165 | 156 | 147 | 139 |
| G 1 C 7 | 248 | ... | ... | ... | ... | ... | 159 | 144 | 132 | 122 | 113 | 106 | 99 | 93 | 88 | 83 |
| G 1 C 8 | 414 | ... | ... | ... | ... | .. | 252 | 229 | 210 | 194 | 180 | 168 | 158 | 148 | 140 | 133 |
| G 1 C 9 | 582 | ... | .. | ... | ... | .. | 346 | 314 | 288 | 266 | 247 | 230 | 216 | 203 | 195 | 182 |
| G 2 C 1 | 130 | ... | ... | ... | .. | 71 | 64 | 58 | 53 | 49 | 45 | 42 | 40 | 37 | ... | ... |
| G 2 C 2 | 227 | ... | ... | ... | ... | 114 | 103 | 93 | 86 | 79 | 73 | 68 | 64 | 60 | ... | ... |
| G 2 C 3 | 340 | ... | ... | ... | ... | 171 | 154 | 140 | 128 | 119 | 110 | 103 | 96 | 91 | ... | ... |
| G 2 C 4 | 180 | ... | ... | ... | ... | 111 | 100 | 91 | 83 | 77 | 71 | 67 | 62 | 59 | ... | ... |
| G 2 C 5 | 294 | ... | ... | ... | ... | 166 | 149 | 135 | 124 | 115 | 106 | 99 | 93 | 88 | ... | ... |
| G 2 C 6 | 440 | ... | ... | ... | ... | 249 | 224 | 203 | 186 | 172 | 160 | 149 | 140 | 131 | ... | ... |
| G 2 C 7 | 360 | ... | ... | ... | ... | 220 | 198 | 179 | 165 | 152 | 142 | 132 | 124 | 117 | ... | ... |
| G 2 C 8 | 540 | ... | ... | ... | ... | 331 | 298 | 271 | 248 | 229 | 213 | 198 | 186 | 175 | ... | ... |
| G 3 C 1 | 98 | ... | ... | ... | 50 | 44 | 40 | 36 | 33 | 31 | 28 | 27 | 25 | ... | ... | ... |
| G 3 C 2 | 178½ | ... | ... | ... | 84 | 75 | 67 | 61 | 56 | 52 | 48 | 45 | 42 | ... | ... | ... |
| G 3 C 3 | 266 | ... | ... | ... | 124 | 110 | 99 | 90 | 83 | 76 | 70 | 66 | 62 | ... | ... | ... |
| G 3 C 4 | 132 | ... | ... | ... | 76 | 69 | 61 | 55 | 51 | 47 | 43 | 41 | 38 | ... | ... | .. |
| G 3 C 5 | 271 | ... | ... | ... | 156 | 139 | 125 | 113 | 104 | 96 | 89 | 83 | 78 | ... | ... | ... |
| G 3 C 6 | 394 | ... | ... | ... | 226 | 201 | 181 | 164 | 150 | 139 | 129 | 120 | 113 | ... | ... | ... |
| G 5 C 1 | 77 | ... | ... | 44 | 38 | 34 | 30 | 28 | 25 | 23 | 22 | 20 | ... | ... | ... | ... |
| G 5 C 2 | 127 | ... | ... | 64 | 56 | 50 | 45 | 41 | 37 | 34 | 32 | 30 | ... | ... | ... | ... |
| G 5 C 3 | 191 | ... | ... | 97 | 85 | 75 | 68 | 62 | 56 | 52 | 48 | 45 | ... | ... | ... | ... |
| G 5 C 4 | 111½ | ... | ... | 72 | 63 | 56 | 50 | 46 | 42 | 39 | 36 | 33 | ... | ... | ... | ... |
| G 5 C 5 | 210 | ... | ... | 129 | 113 | 100 | 90 | 82 | 75 | 69 | 64 | 60 | ... | ... | ... | ... |
| G 5 C 6 | 315 | ... | ... | 193 | 172 | 151 | 136 | 123 | 113 | 104 | 96 | 90 | ... | ... | ... | ... |
| G 6 C 1 | 142 | ... | ... | 64 | 56 | 49 | 45 | 40 | 37 | 34 | 32 | ... | ... | ... | ... | ... |
| G 6 C 2 | 93 | ... | ... | 48 | 42 | 38 | 34 | 31 | 28 | 26 | 24 | ... | ... | ... | ... | ... |
| G 6 C 3 | 164 | ... | ... | 81 | 71 | 63 | 56 | 51 | 47 | 43 | 40 | ... | ... | ... | ... | ... |
| G 6 C 4 | 245 | ... | ... | 119 | 104 | 92 | 83 | 75 | 69 | 64 | 59 | ... | ... | ... | ... | ... |
| G 6 C 5 | 127 | ... | ... | 75 | 66 | 58 | 52 | 48 | 44 | 40 | 37 | ... | ... | ... | ... | ... |
| G 6 C 6 | 212 | ... | ... | 116 | 102 | 90 | 81 | 74 | 68 | 62 | 58 | ... | ... | ... | ... | ... |
| G 6 C 7 | 326 | ... | ... | 169 | 148 | 131 | 118 | 107 | 99 | 92 | 85 | ... | ... | ... | ... | ... |
| G 8 C 1 | 50½ | ... | 21 | 18 | 16 | 14 | 12 | 11 | 10 | ... | ... | ... | ... | ... | ... | ... |
| G 8 C 2 | 96 | ... | 40 | 34 | 30 | 27 | 24 | 22 | 20 | ... | ... | ... | ... | ... | ... | ... |
| G 8 C 3 | 141 | ... | 59 | 51 | 44 | 39 | 35 | 32 | 29 | ... | ... | ... | ... | ... | ... | ... |
| G 8 C 4 | 75 | ... | 41 | 35 | 31 | 27 | 25 | 23 | 20 | ... | ... | ... | ... | ... | ... | ... |
| G 8 C 5 | 121 | ... | 61 | 52 | 45 | 40 | 36 | 33 | 30 | ... | ... | ... | ... | ... | ... | ... |
| G 8 C 6 | 182 | ... | 91 | 78 | 68 | 61 | 55 | 50 | 45 | ... | ... | ... | ... | ... | ... | ... |
| G 8 C 7 | 108 | ... | 69 | 59 | 52 | 46 | 41 | 37 | 34 | ... | ... | ... | ... | ... | ... | ... |
| G 8 C 8 | 162 | ... | 92 | 79 | 69 | 61 | 55 | 50 | 46 | ... | ... | ... | ... | ... | ... | ... |
| G 8 C 9 | 244 | ... | 138 | 118 | 103 | 92 | 83 | 75 | 69 | ... | ... | ... | ... | ... | ... | ... |
| G 10 C 1 | 46½ | 18 | 15 | 13 | 11 | 10 | 9 | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| G 10 C 2 | 87 | 36 | 30 | 26 | 23 | 20 | 18 | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| G 10 C 3 | 56½ | 29 | 24 | 21 | 18 | 16 | 15 | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| G 10 C 4 | 103 | 50 | 42 | 36 | 31 | 28 | 25 | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| G 10 C 5 | 170 | 87 | 73 | 62 | 54 | 48 | 43 | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| G 10 C 6 | 76½ | 45 | 38 | 32 | 28 | 25 | 22 | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| G 10 C 7 | 134 | 73 | 61 | 52 | 46 | 41 | 37 | ... | ... | ... | ... | ... | .. | ... | ... | ... |
| G 10 C 8 | 231 | 135 | 112 | 96 | 85 | 75 | 67 | ... | ... | ... | ... | ... | ... | ... | ... | ... |

TABLE 126.—IRON JOIST GIRDERS: ESTIMATED

(Measures

Factor of

| Reference Number. | Sectional Dimensions, Depth × Width. | Weight per Lineal Foot. | Clear Span in Feet, or | | | | |
|---|---|---|---|---|---|---|---|
| | | | 10 | 12 | 14 | 16 | 18 |
| No. | Inches. | Pounds. | Tons. | Tons. | Tons. | Tons. | Tons. |
| 1 | 22½ × 12 | 245 | 170·6 | 142·8 | 122·0 | 106·8 | 94·8 |
| 2 | 20½ × 12 | 160 | 112·0 | 93·2 | 80·0 | 70·0 | 62·1 |
| 3 | 13½ × 8 | 100 | 39·6 | 33·6 | 29·4 | 25·2 | 22·5 |
| 4 | 17 × 14 | 175 | 112·0 | 102·7 | 79·5 | 69·3 | 61·8 |
| 5 | 16 × 14 | 216 | 110·0 | 91·7 | 78·6 | 69·0 | 61·1 |
| 6 | 14 × 12 | 172 | 96·0 | 80·0 | 68·5 | 59·8 | 53·2 |
| 7 | 11⅜ × 12 | 130 | 66·0 | 55·0 | 47·0 | 40·6 | 36·2 |
| 8 | 12½ × 12 | 110 | 72·0 | 56·0 | 48·0 | 41·0 | 37·0 |
| 9 | 10½ × 12 | 80 | 39·0 | 32·4 | 27·9 | 24·3 | 21·6 |
| 10 | 10½ × 16 | 130 | 59·0 | 49·1 | 41·9 | 36·5 | 32·5 |
| 11 | 9¾ × 8 | 65 | 25·2 | 21·0 | 18·2 | 15·6 | 13·5 |
| 12 | 7½ × 9 | 56 | 19·7 | 16·6 | 14·4 | 12·1 | 10·3 |
| 13 | 13 × 12 | 99 | 44·0 | 38·0 | 31·8 | 28·2 | 24·6 |
| 14 | 11 × 9 | 63 | 25·0 | 21·6 | 18·6 | 16·7 | 14·4 |
| 15 | 12½ × 8 | 57 | 30·0 | 24·0 | 21·7 | 18·7 | 16·9 |
| 16 | 10½ × 6 | 44 | 18·8 | 15·2 | 14·8 | 12·7 | 10·0 |
| 17 | 9¾ × 6 | 35 | 13·4 | 12·1 | 8·8 | 8·4 | 7·8 |
| 18 | 8½ × 6 | 34 | 10·7 | 9·1 | 7·8 | 6·8 | 6·1 |
| 19 | 16½ × 5 | 78 | 36·8 | 30·6 | 26·2 | 23·0 | 20·4 |
| 20 | 18½ × 3¾ | 50 | 29·4 | 24·5 | 21·0 | 18·2 | 16·3 |
| 21 | 20 × 5 | 70 | 45·4 | 37·8 | 32·4 | 28·4 | 25·2 |
| 22 | 20½ × 9 | 84 | 53·2 | 43·2 | 37·2 | 32·4 | 28·0 |
| 23 | 24 × 5 | 88 | 75·8 | 63·1 | 54·1 | 47·6 | 42·5 |
| 24 | 16 × 4 | 46 | 28·0 | 23·3 | 20·0 | 17·2 | 15·1 |
| 25 | 16 × 5 | 67 | 38·0 | 31·2 | 27·1 | 23·5 | 21·1 |
| 26 | 14½ × 4½ | 54 | 28·4 | 23·4 | 20·2 | 17·8 | 15·8 |
| 27 | 14 × 3¾ | 42 | 19·6 | 16·5 | 14·4 | 12·3 | 11·1 |
| 28 | 12 × 5 | 60 | 23·6 | 20·0 | 17·5 | 15·1 | 13·4 |

SAFE PERMANENT DISTRIBUTED LOADS.

Brothers & Co.).

Safety, 1-4th.

| Distances between Supports. | | | | | | | | | Reference Number. |
|---|---|---|---|---|---|---|---|---|---|
| 20 | 22 | 24 | 26 | 28 | 30 | 32 | 34 | 36 | |
| Tons | Tons. | Tons. | Tons. | Tons. | Tons. | Tons. | Tons. | Tons. | No. |
| 85·4 | 77·2 | 71·2 | 65·7 | 60·1 | 56·9 | 53·4 | 50·2 | 47·4 | 1 |
| 55·8 | 50·6 | 46·3 | 42·8 | 38·8 | 36·5 | 35·0 | 32·8 | 31·1 | 2 |
| 19·8 | 18·3 | 16·8 | 15·6 | 14·7 | 13·5 | ... | ... | ... | 3 |
| 56·0 | 50·4 | 46·2 | 42·6 | 39·0 | 36·9 | 34·0 | 32·4 | 30·9 | 4 |
| 55·0 | 50·0 | 45·8 | 42·5 | 39·3 | 36·7 | 34·5 | 32·5 | 30·5 | 5 |
| 48·0 | 42·9 | 39·6 | 37·8 | 34·3 | 33·1 | 29·9 | 28·1 | 26·6 | 6 |
| 33·0 | 29·7 | 27·6 | 25·4 | 23·5 | 21·7 | 20·3 | 19·0 | 18·0 | 7 |
| 34·0 | 30·0 | 28·0 | 26·0 | 24·0 | 22·0 | 20·0 | 19·0 | 18·0 | 8 |
| 19·5 | 17·7 | 16·2 | 15·0 | 13·8 | 12·9 | 12·1 | 11·4 | 10·8 | 9 |
| 29·5 | 26·5 | 24·3 | 22·5 | 20·9 | 19·0 | 18·4 | 17·3 | 16·3 | 10 |
| 12·6 | 11·4 | 10·5 | 9·6 | 9·0 | 8·4 | 7·8 | 7·5 | 6·7 | 11 |
| 9·8 | 7·5 | 6·8 | 6·3 | 5·8 | 5·5 | ... | ... | ... | 12 |
| 22·4 | 20·0 | 18·6 | 17·1 | 15·9 | 14·7 | 13·1 | 14·0 | 12·4 | 13 |
| 13·0 | 11·8 | 10·8 | 10·0 | 9·0 | 8·6 | 8·1 | 7·6 | 7·2 | 14 |
| 15·0 | 13·7 | 12·0 | 11·3 | 10·4 | 9·8 | 9·3 | ... | ... | 15 |
| 9·4 | 8·3 | 7·6 | 7·2 | 7·0 | 6·5 | ... | ... | ... | 16 |
| 6·8 | 6·2 | 4·6 | 4·3 | 4·0 | 3·2 | ... | ... | ... | 17 |
| 5·5 | 5·0 | 4·5 | 4·2 | 3·9 | 3·0 | ... | ... | ... | 18 |
| 18·4 | 16·7 | 15·2 | 14·1 | 13·2 | 12·2 | 11·6 | 10·8 | 10·2 | 19 |
| 14·7 | 13·3 | 12·3 | 11·3 | 10·5 | 9·8 | ... | ... | ... | 20 |
| 22·7 | 20·6 | 18·9 | 17·5 | 16·1 | 15·0 | 14·1 | 13·3 | 12·6 | 21 |
| 26·6 | 23·6 | 21·6 | 20·0 | 18·4 | 17·2 | ... | ... | ... | 22 |
| 37·6 | 34·1 | 31·5 | 29·6 | 27·4 | 25·2 | 3·8 | 22·4 | 21·0 | 23 |
| 14·0 | 12·3 | 11·6 | 10·5 | 9·8 | 8·9 | ... | ... | ... | 24 |
| 19·0 | 17·2 | 15·7 | 14·6 | 13·5 | 12·6 | 11·8 | 11·1 | 10·5 | 25 |
| 14·2 | 12·9 | 11·7 | 10·8 | 10·1 | 9·5 | 8·9 | ... | 7·9 | 26 |
| 9·8 | 8·7 | 8·0 | 7·5 | 7·0 | 6·6 | ... | ... | ... | 27 |
| 11·9 | 10·7 | 10·0 | 9·3 | 8·6 | 8·0 | ... | ... | ... | 28 |

FIGS. 33—44.—SECTIONS OF GIRDERS IN TABLE 126.

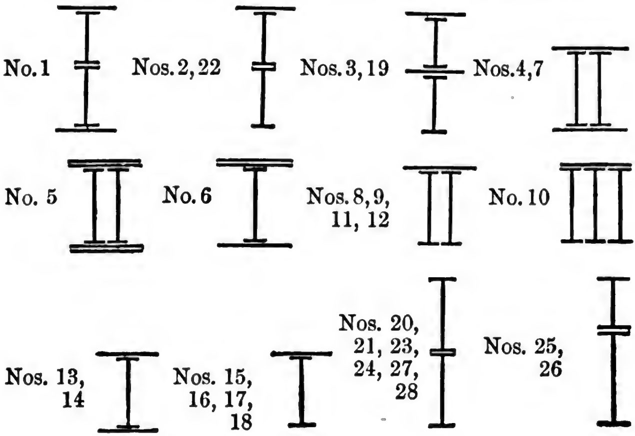



TABLE 127.—ANGLE RIVETED IRON GIRDERS: ESTIMATED SAFE PERMANENT DISTRIBUTED LOAD.

(Measures Brothers & Co.)

| Reference Number. | Sectional Dimensions, Depth × Width. | Weight per Lineal Foot. | Clear Span, or Distance between Supports, in Feet. | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | 10 | 12 | 14 | 16 | 18 | 20 |
| No. | Inches. | Pounds. | Tons. | Tons. | Tons. | Tons. | Tons. | Tons. |
| 1 | 9 × $6\frac{3}{8}$ | 46 | 13 | 11 | 9 | 8 | 7 | 6·5 |
| 2 | 12 × 9 | 112 | ... | 39 | ... | 29 | 26 | 23 |
| 3 | 13 × 16 | 154 | ... | 59 | ... | 44 | ... | 35 |
| 4 | 20 × 18 | 224 | ... | ... | ... | ... | ... | 88 |

| Reference Number. | Sectional Dimensions, Depth × Width. | Weight per Lineal Foot. | Clear Span, or Distance between Supports, in Feet. | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | 22 | 24 | 26 | 30 | 32 | 34 | 36 |
| No. | Inches. | Pounds. | Tons. | Tons. | Tons. | Tons. | Tons. | Tons. | Tons. |
| 1 | 9 × $6\frac{3}{8}$ | 46 | ... | ... | ... | ... | ... | ... | ... |
| 2 | 12 × 9 | 112 | 21 | 19 | ... | ... | ... | ... | ... |
| 3 | 13 × 16 | 154 | ... | 29 | 27 | ... | ... | ... | ... |
| 4 | 20 × 18 | 224 | ... | ... | 67 | 58 | 54 | 51 | 49 |

FIGS. 45—48.—SECTIONS OF GIRDERS IN TABLE 127.

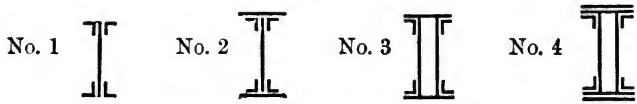



TABLE 128.—ANGLES (IRON).
(The Butterley Company.)

| Reference Number. | Sum of the Sides. | Sectional Dimensions. | Thickness. | Weight per Lineal Foot. |
|---|---|---|---|---|
| No. | Inches. | Inches. | Inch. | Pounds. |
| 1 | 14 | 7 × 7 | ¾ to 1¼ | 26 to 28 |
| 2 | 13½ | 10 × 3½ | 7/16 to ⅝ | 20 to 21¾ |
| 3 | 12½ | 9 × 3½ | 7/16 to ⅝ | 17½ to 23 |
| *4 | 12½ | 8 × 4½ | 7/16 to ⅝ | 17¾ to 22½ |
| *5 | 12½ | 8 × 4½ | ¾ only. | ... |
| *6 | 12 | 6 × 6 | ⅝ to 1 | 24 to 27 |
| 7 | 11½ | 8 × 3½ | ⅜ to ⅝ | 16½ to 19 |
| *8 | 11 | 5½ × 5½ | ½ to ¾ | 19½ to 25¾ |
| *9 | 10½ | 7 × 3½ | 7/16 to ⅝ | 14¾ to 18½ |
| *10 | 10½ | 6½ × 4 | ½ to ⅝ | 17 to 23 |
| *11 | 10 | 7 × 3 | ⅜ to ⅝ | 13 to 16 |
| *12 | 10 | 6 × 4 | ½ to ⅝ | 16 to 23 |
| *13 | 10 | 5 × 5 | ½ to ¾ | 17 to 24 |
| *14 | 9½ | 6 × 3½ | ⅜ to ⅝ | 13½ to 17 |
| *15 | 9 | 6 × 3 | ⅜ to ⅝ | 12½ to 17 |
| *16 | 9 | 5 × 4 | ⅜ to ⅝ | ... |
| *17 | 9 | 4½ × 4½ | ⅜ to ⅝ | 14½ to 21 |
| *18 | 8½ | 5½ × 3 | ⅜ to ⅝ | 10¼ to 16½ |
| *19 | 8½ | 5 × 3½ | ⅜ to ⅝ | 10¼ to 16½ |
| *20 | 8½ | 4¼ × 4¼ | ⅜ to ⅝ | 10¼ to 16½ |
| *21 | 8½ | 4¾ × 3¾ | ⅜ to ⅝ | 13½ to 18 |
| *22 | 8 | 5 × 3 | ⅜ to ⅝ | 9½ to 15½ |
| *23 | 8 | 4½ × 3½ | ⅜ to ⅝ | 9½ to 18½ |
| *24 | 8 | 4 × 4 | ⅜ to ⅝ | 9½ to 17 |
| *25 | 7½ | 4½ × 3 | ⅜ to ⅝ | 9 to 12 |
| *26 | 7½ | 4 × 3½ | ⅜ to ⅝ | 9 to 14½ |
| *27 | 7 | 4 × 3 | 5/16 to ⅝ | 8½ to 13½ |
| *28 | 7 | 3½ × 3½ | ⅜ to ⅝ | 8¼ to 13¼ |
| *29 | 6½ | 4 × 2½ | 5/16 to ⅝ | 6½ to 11½ |
| *30 | 6½ | 3½ × 3 | 5/16 to ⅝ | 6½ to 11½ |
| *31 | 6½ | 3¼ × 3¼ | 5/16 to ⅝ | 6½ to 12¼ |
| *32 | 6 | 4 × 2 | 5/16 to ½ | 6 to 10½ |
| *33 | 6 | 3½ × 2½ | 5/16 to ½ | 6 to 10½ |
| *34 | 6 | 3 × 3 | 5/16 to ½ | 7 to 11½ |
| *35 | 5½ | 3 × 2½ | ¼ to ½ | 4½ to 8½ |

TABLE 128.—ANGLES (IRON) (*continued*).

| Reference Number. | Sum of the Sides. | Sectional Dimensions. | Thickness. | Weight per Lineal Foot. |
|---|---|---|---|---|
| No. | Inches. | Inches. | Inch. | Pounds. |
| *36 | $5\frac{1}{2}$ | $2\frac{3}{4} \times 2\frac{3}{4}$ | $\frac{1}{4}$ to $\frac{1}{2}$ | $5\frac{1}{2}$ to $8\frac{1}{2}$ |
| *37 | $5\frac{1}{4}$ | $2\frac{3}{4} \times 2\frac{1}{2}$ | $\frac{1}{4}$ to $\frac{3}{8}$ | ... |
| *38 | 5 | $3 \times 2$ | $\frac{1}{4}$ to $\frac{3}{8}$ | 4 to $7\frac{1}{2}$ |
| *39 | 5 | $2\frac{1}{2} \times 2\frac{1}{2}$ | $\frac{1}{4}$ to $\frac{3}{8}$ | 4 to $7\frac{1}{2}$ |
| *40 | $4\frac{3}{4}$ | $2\frac{3}{4} \times 2$ | $\frac{3}{16}$ to $\frac{3}{8}$ | ... |
| *41 | $4\frac{1}{2}$ | $3 \times 1\frac{1}{2}$ | $\frac{3}{4}$ only. | ... |
| *42 | $4\frac{1}{2}$ | $2\frac{1}{2} \times 2$ | $\frac{3}{16}$ to $\frac{3}{8}$ | $3\frac{1}{2}$ to 6 |
| *43 | $4\frac{1}{2}$ | $2\frac{1}{4} \times 2\frac{1}{4}$ | $\frac{3}{16}$ to $\frac{3}{8}$ | $3\frac{1}{2}$ to $6\frac{3}{4}$ |
| *44 | 4 | $2 \times 2$ | $\frac{3}{16}$ to $\frac{3}{8}$ | $2\frac{1}{2}$ to $5\frac{1}{4}$ |
| *45 | $3\frac{3}{4}$ | $2 \times 1\frac{3}{4}$ | $\frac{3}{16}$ to $\frac{3}{8}$ | ... |
| *46 | $3\frac{1}{2}$ | $2 \times 1\frac{1}{2}$ | $\frac{3}{16}$ to $\frac{3}{8}$ | $2\frac{3}{4}$ to 4 |
| *47 | $3\frac{1}{2}$ | $1\frac{3}{4} \times 1\frac{3}{4}$ | $\frac{3}{16}$ to $\frac{3}{8}$ | 2 to 4 |
| *48 | $3\frac{1}{4}$ | $1\frac{3}{4} \times 1\frac{1}{2}$ | $\frac{3}{16}$ to $\frac{3}{8}$ | $2\frac{3}{4}$ to 4 |
| *49 | 3 | $1\frac{1}{2} \times 1\frac{1}{2}$ | $\frac{3}{16}$ to $\frac{3}{8}$ | $1\frac{3}{4}$ to $3\frac{1}{4}$ |
| *50 | $2\frac{3}{4}$ | $1\frac{1}{2} \times 1\frac{1}{4}$ | $\frac{3}{16}$ to $\frac{3}{8}$ | ... |
| *51 | $2\frac{1}{2}$ | $1\frac{1}{4} \times 1\frac{1}{4}$ | $\frac{1}{8}$ to $\frac{1}{4}$ | $1\frac{1}{2}$ to $2\frac{3}{4}$ |
| *52 | 2 | $1 \times 1$ | $\frac{1}{8}$ to $\frac{1}{4}$ | 1 to $1\frac{1}{4}$ |
| *53 | $1\frac{3}{4}$ | $\frac{7}{8} \times \frac{7}{8}$ | $\frac{1}{8}$ to $\frac{1}{4}$ | 13 oz. |
| *54 | $1\frac{5}{8}$ | $\frac{15}{16} \times \frac{11}{16}$ | $\frac{1}{8}$ to $\frac{1}{4}$ | ... |
| *55 | $1\frac{1}{2}$ | $\frac{3}{4} \times \frac{3}{4}$ | $\frac{1}{8}$ to $\frac{3}{16}$ | 12 oz. |
| *56 | $1\frac{1}{4}$ | $\frac{5}{8} \times \frac{5}{8}$ | $\frac{1}{8}$ to $\frac{3}{16}$ | ... |

* In iron or steel, others in iron only.

TABLE 129.—CHANNELS (IRON).
(The Butterley Company.)

| Order Number. | Sectional Dimensions. | Thickness of Web. | Average Thickness of Flanges. | Weight per Lineal Foot. |
|---|---|---|---|---|
| No. | Inches. | Inch. | Inch. | Pounds. |
| 1 | $12 \times 3\frac{3}{4}$ | $\frac{11}{16}$ | $\frac{5}{8}$ | 40 to 42 |
| 2 | $10 \times 3\frac{1}{2}$ | $\frac{1}{2}$ | $\frac{1}{2}$ | 28 to 30 |
| 3 | $8 \times 4$ | $\frac{1}{2}$ | $\frac{1}{2}$ | 26 to 28 |
| 4 | $7 \times 2\frac{3}{4}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | ... |
| 5 | $7 \times 2$ | $\frac{5}{8}$ | $\frac{5}{8}$ | 21 to 23 |
| *6 | $6 \times 2\frac{1}{2}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | 11 to 14 |
| *7 | $6 \times 2\frac{1}{2}$ | $\frac{5}{16}$ | $\frac{5}{16}$ | |
| 8 | $5 \times 3\frac{1}{2}$ | $\frac{1}{2}$ | $\frac{1}{2}$ | 18 to 19 |
| *9 | $4\frac{1}{2} \times 1\frac{1}{2}$ | $\frac{1}{2}$ | $\frac{1}{2}$ | 11 to 12 |
| *10 | $4\frac{1}{2} \times \frac{3}{4}$ | $\frac{5}{16}$ | $\frac{5}{16}$ | 6 to $6\frac{1}{2}$ |
| *11 | $4 \times \frac{3}{4}$ | $\frac{5}{16}$ | $\frac{5}{16}$ | $5\frac{3}{4}$ to 6 |
| 12 | $3\frac{1}{2} \times 5$ and $2\frac{1}{2}$ | $\frac{1}{2}$ | $\frac{1}{2}$ | 17 to 18 |
| *13 | $2\frac{1}{2} \times 1\frac{1}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | 5 to 6 |

* In iron or steel; others in iron only.

TABLE 130.—TEES (IRON) (The Butterley Company).

| Order Number. | Sum of the Flange and Web. | Sectional Dimensions. | | | Thickness. | | Thickness. | | Thickness. | | Weight per Lineal Foot. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Flange. | Web. | Flange. | Web. | Flange. | Web. | |
| No. | Inches. | Ins. (Flange). | | Ins. (Web). | Inch. | Inch. | Inch. | Inch. | Inch. | Inch. | Pounds. |
| 1 | 20 | 10 | × | 10 | $1\frac{1}{8}$ | $\frac{13}{16}$ | $1\frac{1}{8}$ | $\frac{7}{8}$ | ... | ... | 69 to 70 |
| 2 | $16\frac{1}{4}$ | $6\frac{1}{2}$ | × | $9\frac{3}{4}$ | $1\frac{5}{8}$ | $\frac{3}{4}$ | ... | ... | ... | ... | 57 to 60 |
| 3 | $14\frac{1}{4}$ | $6\frac{1}{4}$ | × | 8 | $\frac{3}{4}$ | $\frac{9}{16}$ full | $\frac{3}{4}$ | $\frac{5}{8}$ | $\frac{3}{4}$ | $\frac{11}{16}$ | 32 to 34 |
| 4 | $12\frac{1}{4}$ | $6\frac{1}{4}$ | × | 6 | $\frac{3}{4}$ | $\frac{9}{16}$ | $\frac{3}{4}$ | $\frac{5}{8}$ | $\frac{3}{4}$ | $\frac{11}{16}$ | 28 to 30 |
| 5 | 12 | 6 | × | 6 | $\frac{5}{8}$ | $\frac{9}{16}$ | ... | ... | ... | ... | 23 to 25 |
| 6 | $10\frac{1}{2}$ | 7 | × | $3\frac{1}{2}$ | $\frac{1}{2}$ | $\frac{1}{2}$ | ... | ... | ... | ... | 17 to 18 |
| 7 | *10 | 6 | × | 4 | $\frac{1}{2}$ | $\frac{1}{2}$ | $\frac{5}{8}$ | $\frac{5}{8}$ | ... | ... | 15 to 20 |
| 8 | *10 | 5 | × | 5 | $\frac{1}{2}$ | $\frac{1}{2}$ | $\frac{1}{2}$ | $\frac{9}{16}$ | $\frac{1}{2}$ | $\frac{5}{8}$ | 16 to 18 |
| 9 | $*9\frac{3}{8}$ | $5\frac{1}{2}$ | × | $3\frac{7}{8}$ | $\frac{1}{2}$ | $\frac{11}{16}$ | $\frac{1}{2}$ | $\frac{3}{4}$ | ... | ... | 18 |
| 10 | *9 | 5 | × | 4 | $\frac{1}{2}$ | $\frac{1}{2}$ | $\frac{1}{2}$ | $\frac{9}{16}$ | ... | ... | $14\frac{1}{2}$ to 16 |
| 11 | *9 | 6 | × | 3 | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{1}{2}$ | $\frac{1}{2}$ | ... | ... | 11 to $14\frac{1}{2}$ |
| 12 | $*8\frac{1}{2}$ | $5\frac{1}{2}$ | × | 3 | $\frac{1}{2}$ | $\frac{1}{2}$ | $\frac{1}{2}$ | $\frac{9}{16}$ | ... | ... | $13\frac{1}{4}$ |
| 13 | $*8\frac{1}{2}$ | 5 | × | $3\frac{1}{2}$ | $\frac{1}{2}$ | $\frac{3}{4}$ | $\frac{1}{2}$ | $\frac{13}{16}$ | ... | ... | 16 |
| 14 | *8 | 4 | × | 4 | $\frac{1}{2}$ | $\frac{1}{2}$ | $\frac{1}{2}$ | $\frac{9}{16}$ | ... | ... | $12\frac{1}{4}$ |
| 15 | *8 | 5 | × | 3 | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{1}{2}$ | $\frac{1}{2}$ | ... | ... | $9\frac{1}{2}$ to $12\frac{1}{2}$ |
| 16 | *7 | 4 | × | 3 | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{7}{16}$ | $\frac{7}{16}$ | $\frac{1}{2}$ | $\frac{1}{2}$ | 11 |
| 17 | *7 | $3\frac{1}{2}$ | × | $3\frac{1}{2}$ | $\frac{1}{2}$ | $\frac{1}{2}$ | $\frac{1}{2}$ | $\frac{9}{16}$ | ... | ... | 11 |
| 18 | $*6\frac{1}{2}$ | $3\frac{1}{2}$ | × | 3 | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{1}{2}$ | $\frac{1}{2}$ | ... | ... | $7\frac{3}{4}$ to $10\frac{1}{4}$ |

* In iron or steel; others in iron only.

TABLE 130.—TEES (IRON) (*continued*).

| Order Number. | Sum of the Flange and Web. | Sectional Dimensions. | | Thickness. | | Thickness. | | Thickness. | | Weight per Lineal Foot. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Flange. | Web. | Flange. | Web. | Flange. | Web. | |
| No. | Inches. | Ins. (Flange). | Ins. (Web). | Inch. | Inch. | Inch. | Inch. | Inch. | Inch. | Pounds. |
| 19 | *6½ | 3 × | 3½ | ½ | ½ | ... | ... | ... | ... | 10 |
| 20 | *6 | 4 × | 2 | ⅜ | ⅜ | 7/16 | 7/16 | ... | ... | 7 |
| 21 | *6 | 3 × | 3 | ⅜ | ⅜ | ½ | ½ | ... | ... | 7 |
| 22 | *5½ | 3 × | 2½ | ⅜ | ⅜ | 7/16 | 7/16 | ½ | ½ | 9 |
| 23 | *5½ | 2¾ × | 2¾ | 5/16 | 5/16 | ⅜ | ⅜ | 7/16 | 7/16 | ... |
| 24 | *5 | 3 × | 2 | 5/16 | 5/16 | ⅜ | ⅜ | ... | ... | 6 |
| 25 | *5 | 2½ × | 2½ | ¼ | ¼ | 5/16 | 5/16 | ⅜ | ⅜ | 5¾ |
| 26 | *4½ | 2½ × | 2 | ¼ | ¼ | 5/16 | 5/16 | ⅜ | ⅜ | ... |
| 27 | *4½ | 2¼ × | 2¼ | ¼ | ¼ | 5/16 | 5/16 | ⅜ | ⅜ | 5 |
| 28 | *4¼ | 2½ × | 1¾ | ¼ | ¼ | 5/16 | 5/16 | ... | ... | 3½ |
| 29 | *4 | 2 × | 2 | ¼ | ¼ | 5/16 | 5/16 | ⅜ | ⅜ | 3 to 4½ |
| 30 | *3½ | 2 × | 1½ | ¼ | ¼ | 5/16 | 5/16 | ⅜ | ⅜ | ... |
| 31 | *3½ | 1¾ × | 1¾ | 3/16 | 3/16 | ¼ | ¼ | 5/16 | 5/16 | 3 |
| 32 | *3½ | 1½ × | 2 | 5/16 | 5/16 | ... | ... | ... | ... | ... |
| 33 | *3 | 1½ × | 1½ | ⅛ | ⅛ | 3/16 | 3/16 | ¼ | ¼ | 2 |
| 34 | *2½ | 1¼ × | 1¼ | ⅛ | ⅛ | 3/16 | 3/16 | ¼ | ¼ | ... |
| 35 | *2 | 1 × | 1 | ⅛ | ⅛ | 3/16 | 3/16 | ¼ | ¼ | ·8 to 1·2 |
| 36 | *1¾ | ⅞ × | ⅞ | ⅛ | ⅛ | 3/16 | 3/16 | ¼ | ¼ | ... |
| 37 | *1½ | ¾ × | ¾ | ⅛ | ⅛ | 3/16 | 3/16 | ¼ | ¼ | ... |

* In iron or steel.

## TABLE 131.—BULB BARS (IRON).
(The Butterley Company.)

| Order Number. | Width. | Thickness of Bulb. | Thickness of Web. | Weight per Lineal Foot. |
|---|---|---|---|---|
| | Inches. | Inches. | Inch. | Pounds. |
| 1 | 10 | $2\frac{1}{2}$ to $2\frac{5}{8}$ | $\frac{1}{2}$ to $\frac{5}{8}$ | 23 |
| 2 | 6 | $3\frac{1}{4}$ to $3\frac{3}{8}$ | $\frac{1}{2}$ full to $\frac{5}{8}$ full | 21 to 24 |
| 3 | 6 | $2\frac{1}{4}$ to $2\frac{3}{8}$ | $\frac{1}{2}$ to $\frac{5}{8}$ | $13\frac{1}{2}$ to 18 |

Rolled in iron only.

## TABLE 132.—BULB TEES OR DECK BEAMS (IRON).
(The Butterley Company.)

| Depth (Web). | Width of Flange. | Width of Bulb. | Minimum Thickness of Web. | Weight per Lineal Foot in Iron. |
|---|---|---|---|---|
| Inches. | Inches. | Inches. | Inch. | Pounds. |
| 16 | $6\frac{1}{4}$ | $3\frac{1}{4}$ | $\frac{5}{8}$ bare | 58 to 62 |
| 16 | $6\frac{1}{4}$ | $2\frac{1}{4}$ | $\frac{5}{8}$ bare | 53 to 57 |
| 15 | $6\frac{1}{4}$ | $3\frac{1}{4}$ | $\frac{5}{8}$ bare | 56 to 60 |
| 15 | $6\frac{1}{4}$ | $2\frac{1}{4}$ | $\frac{5}{8}$ bare | 51 to 55 |
| 14 | $6\frac{1}{4}$ | $3\frac{1}{4}$ | $\frac{5}{8}$ bare | 54 to 58 |
| 14 | $6\frac{1}{4}$ | $2\frac{1}{4}$ | $\frac{5}{8}$ bare | 50 to 54 |
| 13 | $6\frac{1}{4}$ | $3\frac{1}{4}$ | $\frac{5}{8}$ bare | 52 to 56 |
| 13 | $6\frac{1}{4}$ | $2\frac{1}{4}$ | $\frac{5}{8}$ bare | 48 to 52 |
| 12 | $6\frac{1}{4}$ | $3\frac{1}{4}$ | $\frac{5}{8}$ bare | 50 to 54 |
| 12 | $6\frac{1}{4}$ | $2\frac{1}{4}$ | $\frac{5}{8}$ bare | 46 to 50 |
| 11 | $6\frac{1}{2}$ | $2\frac{1}{4}$ | $\frac{1}{2}$ bare | 45 to 49 |
| †11 | 6 | $2\frac{1}{4}$ | $\frac{1}{2}$ bare | 36 to 40 |
| 10 | 6 | $2\frac{1}{8}$ | $\frac{1}{2}$ bare | 35 to 39 |
| †10 | 6 | 2 | $\frac{1}{2}$ bare | 32 to 36 |
| †$9\frac{1}{2}$ | $5\frac{1}{2}$ | $1\frac{3}{4}$ | $\frac{1}{2}$ bare | 31 to 35 |
| 9 | $5\frac{1}{2}$ | 2 | $\frac{7}{36}$ | 32 to 36 |
| 9 | $6\frac{1}{2}$ | 2 | $\frac{1}{2}$ bare | 35 to 39 |
| 9 | $5\frac{1}{4}$ | $1\frac{3}{4}$ | $\frac{15}{32}$ | 29 to 29 |
| $8\frac{1}{2}$ | $5\frac{1}{4}$ | $1\frac{3}{4}$ | $\frac{8}{20}$ | 25 to 28 |
| 8 | $6\frac{1}{4}$ | $1\frac{3}{4}$ | $\frac{9}{16}$ bare | 31 to 33 |
| 8 | $5\frac{1}{4}$ | $1\frac{7}{8}$ | $\frac{7}{16}$ | 27 to 30 |
| †8 | 5 | $1\frac{3}{4}$ | $\frac{3}{8}$ full | 22 to 24 |
| 7 | 5 | $1\frac{3}{4}$ | $\frac{3}{8}$ | 23 to 26 |
| †7 | 5 | $1\frac{5}{8}$ | $\frac{3}{8}$ | 19 to 22 |
| 6 | 5 | $1\frac{1}{2}$ | $\frac{3}{8}$ | 19 to 22 |
| *6 | $4\frac{1}{2}$ | $1\frac{9}{16}$ | $\frac{3}{8}$ | 16 to 18 |
| *6 | 4 | $1\frac{1}{2}$ | $\frac{7}{16}$ | 18 to 20 |
| *5 | 4 | $1\frac{1}{2}$ | $\frac{3}{8}$ | 14 to 16 |
| 4 | 3 | $1\frac{1}{4}$ | $\frac{5}{16}$ | 9 to 10 |

* In iron or steel; † in steel only; the others in iron only.

### TABLE 133.—BULB ANGLES (IRON).
(The Butterley Company.)

| Order Number. | Depth (Web). | Width of Flange. | Width of Bulb. | Thickness of Web. | Weight per Lineal Foot. |
|---|---|---|---|---|---|
| No. | Inches. | Inches. | Inches. | Inch. | Pounds. |
| 1 | 12 | $3\frac{1}{2}$ | $2\frac{1}{4}$ | $\frac{1}{2}$ to $\frac{5}{8}$ | 33 to 38 |
| *2 | 9 | $3\frac{1}{2}$ | $2\frac{1}{4}$ | $\frac{7}{16}$ to $\frac{5}{8}$ | $24\frac{1}{2}$ to 31 |
| *3 | 8 | $2\frac{1}{2}$ | 1 | $\frac{5}{16}$ to $\frac{1}{2}$ | ... |
| *4 | 7 | $3\frac{3}{4}$ | $1\frac{1}{8}$ | $\frac{1}{2}$ to $\frac{5}{8}$ | 19 to 22 |
| *5 | $6\frac{1}{2}$ | $3\frac{1}{2}$ | $\frac{15}{16}$ | $\frac{1}{2}$ to $\frac{5}{8}$ | 16 to 20 |
| *6 | 6 | $2\frac{1}{2}$ | $\frac{7}{8}$ | $\frac{5}{16}$ to $\frac{1}{2}$ | ... |
| *7 | 5 | $2\frac{1}{2}$ | $\frac{15}{16}$ | $\frac{3}{8}$ to $\frac{1}{2}$ | 11 to 13 |

* In iron or steel; other in iron only.

### TABLE 134.—SPACE OR Z ANGLES (IRON).
(The Butterley Company.)

| Order Number. | Depth of Web. | Width of Flanges. | Thickness. | Weight per Lineal Foot. |
|---|---|---|---|---|
| No. | Inches. | Inches. | Inch. | Pounds. |
| 1 | 10 | $3\frac{1}{2}$ and $3\frac{1}{2}$ | $\frac{7}{16}$ to $\frac{9}{16}$ | 24 to 31 |
| 2 | 9 | 3 and 3 | $\frac{3}{8}$ to $\frac{1}{2}$ | ... |
| 3 | 6 | $3\frac{1}{2}$ and 3 | $\frac{3}{8}$ to $\frac{1}{2}$ | 15 to 20 |
| 4 | 5 | 3 and $2\frac{1}{2}$ | $\frac{1}{2}$ to $\frac{5}{8}$ | 16 to 20 |
| 5 | 4 | $3\frac{1}{2}$ and 3 | $\frac{3}{8}$ to $\frac{9}{16}$ | $12\frac{1}{2}$ to 20 |
| 6 | 4 | $2\frac{1}{2}$ and $2\frac{1}{2}$ | $\frac{3}{8}$ to $\frac{1}{2}$ | 11 to 14 |
| 7 | 3 | 3 and $2\frac{1}{2}$ | $\frac{7}{16}$ to $\frac{5}{8}$ | 11 to 15 |
| 8 | 3 | $2\frac{1}{4}$ and $2\frac{1}{4}$ | $\frac{3}{8}$ to $\frac{1}{2}$ | 9 to 12 |
| 9 | $2\frac{5}{8}$ | $2\frac{1}{2}$ and $2\frac{1}{4}$ | $\frac{7}{16}$ to $\frac{5}{8}$ | 10 to 14 |
| 10 | $2\frac{1}{2}$ | $2\frac{1}{2}$ and $2\frac{1}{2}$ | $\frac{3}{8}$ to $\frac{1}{2}$ | 9 to 12 |

Can be rolled in iron or steel.

### TABLE 135.—Z ANGLES (STEEL).
(Dorman, Long & Co., Limited.)

| Depth and Thickness (Web). | Width and Thickness of Flanges. | Depth and Thickness (Web). | Width and Thickness of Flanges. |
|---|---|---|---|
| Ins. In. | Ins. In. | Ins. In. | Ins. In. |
| 8 × $\frac{1}{2}$ to $\frac{5}{8}$ | $3\frac{1}{2}$ and $3\frac{1}{2}$ × $\frac{1}{2}$ & $\frac{9}{16}$ | $5\frac{1}{2}$ × $\frac{3}{8}$ to $\frac{5}{8}$ | 3 and 3 × $\frac{3}{8}$ to $\frac{5}{8}$ |
| 7 × $\frac{3}{8}$ | 3 and 3 × $\frac{3}{8}$ | 5 × $\frac{3}{8}$ to $\frac{5}{8}$ | $3\frac{1}{2}$ and $3\frac{1}{2}$ × $\frac{3}{8}$ to $\frac{5}{8}$ |
| 6 × $\frac{3}{8}$ to $\frac{5}{8}$ | $3\frac{1}{2}$ and $3\frac{1}{2}$ × $\frac{3}{8}$ to $\frac{5}{8}$ | 5 × $\frac{3}{8}$ to $\frac{5}{8}$ | 3 and 3 × $\frac{3}{8}$ to $\frac{5}{8}$ |
| 6 × $\frac{3}{8}$ to $\frac{5}{8}$ | $3\frac{1}{2}$ and 3 × $\frac{3}{8}$ to $\frac{5}{8}$ | 5 × $\frac{3}{8}$ to $\frac{5}{8}$ | $2\frac{1}{2}$ and 3 × $\frac{3}{8}$ to $\frac{5}{8}$ |
| 6 × $\frac{3}{8}$ to $\frac{5}{8}$ | 3 and 3 × $\frac{3}{8}$ to $\frac{5}{8}$ | 4 × $\frac{3}{8}$ to $\frac{5}{8}$ | 3 and 3 × $\frac{3}{8}$ to $\frac{5}{8}$ |
| $5\frac{1}{2}$ × $\frac{3}{8}$ to $\frac{5}{8}$ | $3\frac{1}{2}$ and $3\frac{1}{2}$ × $\frac{3}{8}$ to $\frac{5}{8}$ | | |

## TABLE 136.—ANGLES (STEEL).

(Dorman, Long & Co., Limited.)

| Sectional Dimensions. | Thickness. | Sectional Dimensions. | Thickness. | Sectional Dimensions. | Thickness. |
|---|---|---|---|---|---|
| EQUAL SIDED. | | UNEQUAL SIDED. | | | |
| Inches. | Inch. | Inches. | Inch. | Inches. | Inch. |
| $8 \times 8$ | $\frac{1}{2}$ to 1 | $7 \times 4$ | $\frac{7}{16}$ to $\frac{7}{8}$ | $4\frac{1}{2} \times 3\frac{1}{2}$ | $\frac{3}{8}$ to $\frac{7}{8}$ |
| $7 \times 7$ | $\frac{1}{2}$ to 1 | $7 \times 3$ | $\frac{3}{8}$ to $\frac{3}{4}$ | $4\frac{1}{2} \times 3$ | $\frac{5}{16}$ to $\frac{3}{4}$ |
| $6 \times 6$ | $\frac{1}{2}$ to 1 | $6\frac{1}{2} \times 4\frac{1}{2}$ | $\frac{7}{16}$ to 1 | $4\frac{1}{2} \times 2\frac{1}{2}$ | $\frac{3}{8}$ to $\frac{3}{4}$ |
| $5 \times 5$ | $\frac{7}{16}$ to $\frac{7}{8}$ | $6\frac{1}{2} \times 4$ | $\frac{7}{16}$ to $\frac{13}{16}$ | $4 \times 3\frac{1}{2}$ | $\frac{3}{8}$ to $\frac{7}{8}$ |
| $4\frac{1}{2} \times 4\frac{1}{2}$ | $\frac{3}{8}$ to $\frac{7}{8}$ | $6\frac{1}{2} \times 3$ | $\frac{3}{8}$ to $\frac{3}{4}$ | $4 \times 3$ | $\frac{5}{16}$ to $\frac{3}{4}$ |
| $4 \times 4$ | $\frac{5}{16}$ to $\frac{11}{16}$ | $6 \times 5$ | $\frac{7}{16}$ to 1 | $4 \times 2\frac{1}{2}$ | $\frac{3}{8}$ to $\frac{3}{4}$ |
| $3\frac{1}{2} \times 3\frac{1}{2}$ | $\frac{5}{16}$ to $\frac{3}{4}$ | $6 \times 4$ | $\frac{3}{8}$ to $\frac{7}{8}$ | $3\frac{1}{2} \times 3$ | $\frac{5}{16}$ to $\frac{11}{16}$ |
| $3 \times 3$ | $\frac{1}{4}$ to $\frac{11}{16}$ | $6 \times 3\frac{1}{2}$ | $\frac{3}{8}$ to $\frac{7}{8}$ | $3\frac{1}{2} \times 2\frac{1}{2}$ | $\frac{5}{16}$ to $\frac{5}{8}$ |
| $2\frac{3}{4} \times 2\frac{3}{4}$ | $\frac{1}{4}$ to $\frac{5}{8}$ | $6 \times 3$ | $\frac{3}{8}$ to $\frac{3}{4}$ | $3\frac{1}{2} \times 1\frac{3}{4}$ | $\frac{7}{16}$ and $\frac{3}{8}$ |
| $2\frac{1}{2} \times 2\frac{1}{2}$ | $\frac{1}{4}$ to $\frac{5}{8}$ | $5\frac{1}{2} \times 4$ | $\frac{3}{8}$ to $\frac{7}{8}$ | $3\frac{1}{2} \times 1\frac{3}{4}$ | $\frac{3}{8}$ and $\frac{5}{16}$ |
| $2\frac{1}{4} \times 2\frac{1}{4}$ | $\frac{1}{4}$ to $\frac{1}{2}$ | $5\frac{1}{2} \times 3\frac{1}{2}$ | $\frac{3}{8}$ to $\frac{13}{16}$ | $3\frac{1}{2} \times 1\frac{3}{4}$ | $\frac{5}{16}$ and $\frac{1}{4}$ |
| $2 \times 2$ | $\frac{3}{16}$ to $\frac{3}{8}$ | $5\frac{1}{2} \times 3$ | $\frac{3}{8}$ to $\frac{3}{4}$ | $3 \times 2\frac{3}{4}$ | $\frac{1}{4}$ to $\frac{11}{16}$ |
| $1\frac{3}{4} \times 1\frac{3}{4}$ | $\frac{3}{16}$ to $\frac{3}{8}$ | $5 \times 4$ | $\frac{3}{8}$ to $\frac{13}{16}$ | $3 \times 2\frac{1}{2}$ | $\frac{1}{4}$ to $\frac{3}{8}$ |
| $1\frac{1}{2} \times 1\frac{1}{2}$ | $\frac{1}{8}$ to $\frac{5}{16}$ | $5 \times 3\frac{1}{2}$ | $\frac{5}{16}$ to $\frac{3}{4}$ | $3 \times 2$ | $\frac{1}{4}$ to $\frac{9}{16}$ |
| $1\frac{1}{4} \times 1\frac{1}{4}$ | $\frac{1}{8}$ to $\frac{5}{16}$ | $5 \times 3$ | $\frac{5}{16}$ to $\frac{3}{4}$ | $2\frac{1}{2} \times 2$ | $\frac{1}{4}$ to $\frac{1}{2}$ |
| $1 \times 1$ | $\frac{3}{32}$ to $\frac{1}{4}$ | $4\frac{1}{2} \times 4$ | $\frac{3}{8}$ to $\frac{7}{8}$ | $3 \times 1\frac{1}{2}$ | $\frac{5}{16}$ to $\frac{3}{8}$ |
| | | | | $2 \times 1\frac{1}{2}$ | $\frac{3}{16}$ to $\frac{3}{8}$ |

## TABLE 137.—TEES (STEEL).

(Dorman, Long & Co., Limited.)

| Width of Flange. | Depth (Web). | Thickness. | Width of Flange. | Depth (Web). | Thickness. |
|---|---|---|---|---|---|
| Inches. | Inches. | Inch. | Inches. | Inches. | Inch. |
| 6 | 3 | $\frac{3}{8}$ and $\frac{1}{2}$ | 3 | 3 | $\frac{3}{8}$ |
| 5 | 3 | $\frac{3}{8}$ and $\frac{1}{2}$ | 3 | $2\frac{1}{2}$ | $\frac{3}{8}$ |
| 5 | $2\frac{1}{2}$ | $\frac{3}{8}$ | $2\frac{1}{2}$ | $2\frac{1}{2}$ | $\frac{1}{4}$ |
| $4\frac{1}{2}$ | $3\frac{1}{2}$ | $\frac{7}{16}$ | $2\frac{1}{4}$ | $2\frac{1}{4}$ | $\frac{1}{4}$ |
| 4 | 5 | $\frac{1}{2}$ | 2 | 2 | $\frac{1}{4}$ |
| 4 | 4 | $\frac{1}{2}$ | 2 | $1\frac{1}{2}$ | $\frac{1}{4}$ |
| 4 | $3\frac{1}{2}$ | $\frac{3}{8}$ | 2 | $1\frac{1}{4}$ | $\frac{1}{4}$ |
| 4 | 3 | $\frac{3}{8}$ | $1\frac{3}{4}$ | $1\frac{3}{4}$ | $\frac{3}{16}$ |
| $3\frac{1}{2}$ | $3\frac{1}{2}$ | $\frac{3}{8}$ | $1\frac{1}{2}$ | 2 | $\frac{1}{4}$ |
| $3\frac{1}{2}$ | 3 | $\frac{3}{8}$ | $1\frac{1}{2}$ | $1\frac{1}{2}$ | $\frac{1}{4}$ |

## Table 138.—Channels (Steel).
(Dorman, Long & Co., Limited.)

| Reference Number. | Sectional Dimensions. | Web Thickness. | Flange Thickness. | Sectional Area. | Reference Number. | Sectional Dimensions. | Web Thickness. | Flange Thickness. | Sectional Area. |
|---|---|---|---|---|---|---|---|---|---|
| No. | Inches. | Inch. | Inch. | Sq. In. | No. | Inches. | Inch. | Inch. | Sq. In. |
| C 12A | 12 × 3½ | ½ | $\frac{9}{16}$ | 9·37 | C 7 | 6 × 4 | ⅜ | ⅝ | 7·81 |
| C 12 | 12 × 3½ | ½ | ½ | 9·0 | C 6 | 6 × 3 | ⅜ | $\frac{7}{16}$ | 4·54 |
| C 11A | 10 × 4 | ½ | $\frac{7}{16}$ | 8·06 | C 6A | 6 × 2½ | $\frac{7}{16}$ | $\frac{7}{16}$ | 4·42 |
| C 11 | 10 × 3 | $\frac{7}{16}$ | $\frac{7}{16}$ | 6·61 | C 6B | 6 × 3⅛ | $\frac{7}{16}$ | $\frac{7}{16}$ | 5·49 |
| C 9 | 8 × 3½ | ½ | ½ | 7·0 | C 5 | 5⅛ × 2⅞ | $\frac{7}{16}$ | ½ | 4·67 |
| C 9A | 7⅞ × 3¾ | ½ | ½ | 7·18 | C 4 | 4½ × 2 | $\frac{7}{16}$ | $\frac{7}{16}$ | 3·33 |
| C 8A | 7 × 3½ | ½ | ½ | 6·5 | C 2 | 4 × 3 | ⅜ | $\frac{9}{16}$ | 4·81 |
| C 8 | 7 × 3 | ½ | ½ | 6·0 | C 1 | 3½ × 1½ | ⅜ | ½ | 2·43 |

## Table 139.—Bulb Bars (Steel).
(Dorman, Long & Co., Limited.)

| Length. | Thickness. | Length. | Thickness. | Length. | Thickness. |
|---|---|---|---|---|---|
| Inches. | Inch. | Inches. | Inch. | Inches. | Inch. |
| 12 | $\frac{10}{20}$ to $\frac{14}{20}$ | 9 | $\frac{9}{20}$ to $\frac{11}{20}$ | 7½ | $\frac{7}{20}$ to $\frac{9}{20}$ |
| 11 | $\frac{10}{20}$ to $\frac{13}{20}$ | 8½ | $\frac{8}{20}$ to $\frac{10}{20}$ | 7 | $\frac{7}{20}$ to $\frac{9}{20}$ |
| 10½ | $\frac{10}{20}$ to $\frac{12}{20}$ | 8 | $\frac{8}{20}$ to $\frac{10}{20}$ | 6½ | $\frac{6}{20}$ to $\frac{8}{20}$ |
| 10 | $\frac{10}{20}$ to $\frac{12}{20}$ | 7½ | 1⅛ to 1½ | 6 | $\frac{6}{20}$ to $\frac{8}{20}$ |
| 9½ | $\frac{9}{20}$ to $\frac{11}{20}$ | | | | |

## Table 140.—Bulb Angles (Steel).
(Dorman, Long & Co., Limited.)

| Depth (Web). | Width of Flange. | Web Thickness. | Flange Thickness. | Depth (Web). | Width of Flange. | Web Thickness. | Flange Thickness. |
|---|---|---|---|---|---|---|---|
| Inches. | Inches. | Inch. | Inch. | Inches. | Inches. | Inch. | Inch. |
| 9 | 3½ | $\frac{10}{20}$ to $\frac{12}{20}$ | $\frac{11}{20}$ | 6½ | 3 | $\frac{8}{20}$ to $\frac{11}{20}$ | $\frac{8}{20}$ |
| 8 | 3 | $\frac{10}{20}$ to $\frac{12}{20}$ | $\frac{10}{20}$ | 6 | 3½ | $\frac{8}{20}$ to $\frac{12}{20}$ | $\frac{8}{20}$ |
| 7½ | 3 | $\frac{9}{20}$ to $\frac{12}{20}$ | $\frac{9}{20}$ | 6 | 3 | $\frac{8}{20}$ to $\frac{11}{20}$ | $\frac{8}{20}$ |
| 7 | 3 | $\frac{8}{20}$ to $\frac{11}{20}$ | $\frac{9}{20}$ | 5½ | 3 | $\frac{8}{20}$ to $\frac{11}{20}$ | $\frac{8}{20}$ |
| 6½ | 3½ | $\frac{9}{20}$ to $\frac{11}{20}$ | $\frac{10}{20}$ | 3¾ | 2½ | $\frac{9}{20}$ & $\frac{11}{20}$ | $\frac{9}{20}$ |
| 9 | 3 | $\frac{10}{20}$ to $\frac{12}{20}$ | | | | | |

## TABLE 141.—ENGLISH STEEL COMPOUND GIRDERS.
(Dorman, Long & Co., Limited.)

| No. of Section. | Weight per Foot in Pounds. | Sizes in Inches. | Compounded of | Distributed Loads in Tons that One Foot will Carry, being ¼th of Breaking Strain. | ⅕th of Breaking Strain. |
|---|---|---|---|---|---|
| G 1 C 1 | 144 | 21¼ × 12 | 1 G 1 and 2 ⅝-in. plates | 1533·43 | 1226·72 |
| G 1 C 2 | 260 | 21¼ × 18 | 2 G 1 ,, 2 ,, ,, | 2654·36 | 2123·48 |
| G 1 C 3 | 377 | 21¼ × 24 | 3 G 1 ,, 2 ,, ,, | 3775·29 | 3020·23 |
| G 1 C 4 | 195 | 22½ × 12 | 1 G 1 ,, 4 ,, ,, | 2335·51 | 1868·4 |
| G 1 C 5 | 335 | 22½ × 18 | 2 G 1 ,, 4 ,, ,, | 3821·02 | 3056·81 |
| G 1 C 6 | 480 | 22½ × 24 | 3 G 1 ,, 4 ,, ,, | 5306·54 | 4245·23 |
| G 1 C 7 | 248 | 23¾ × 12 | 1 G 1 ,, 6 ,, ,, | 3183·43 | 2546·74 |
| G 1 C 8 | 414 | 23¾ × 18 | 2 G 1 ,, 6 ,, ,, | 5054·36 | 4043·48 |
| G 1 C 9 | 582 | 23¾ × 24 | 3 G 1 ,, 6 ,, , | 6925·29 | 5540·23 |
| G 2 C 1 | 130 | 19¼ × 12 | 1 G 2 ,, 2 ,, ,, | 1279·19 | 1023·35 |
| G 2 C 2 | 227 | 19¼ × 16 | 2 G 2 ,, 2 ,, ,, | 2061·72 | 1649·37 |
| G 2 C 3 | 340 | 19¼ × 24 | 3 G 2 ,, 2 ,, ,, | 3092·59 | 2474·07 |
| G 2 C 4 | 180 | 20½ × 12 | 1 G 2 ,, 4 ,, ,, | 2007·94 | 1606·35 |
| G 2 C 5 | 294 | 20½ × 16 | 2 G 2 ,, 4 ,, ,, | 2989·22 | 2391·37 |
| G 2 C 6 | 440 | 20½ × 24 | 3 G 2 ,, 4 ,, ,, | 4483·84 | 3587·07 |
| G 2 C 7 | 360 | 21¾ × 16 | 2 G 2 ,, 6 ,, ,, | 3975·06 | 3180·04 |
| G 2 C 8 | 540 | 21¾ × 24 | 3 G 2 ,, 6 ,, ,, | 5962·59 | 4770·07 |
| G 3 C 1 | 98 | 17 × 10 | 1 G 3 and 2 ½-in. plates | 808·89 | 647·11 |
| G 3 C 2 | 178½ | 17 × 14 | 2 G 3 ,, 2 ,, ,, | 1353·78 | 1083·02 |
| G 3 C 3 | 266 | 17 × 20 | 3 G 3 ,, 2 ,, ,, | 1986·67 | 1589·33 |
| G 3 C 4 | 132 | 18 × 10 | 1 G 3 ,, 4 ,, ,, | 1228·89 | 983·11 |
| G 3 C 5 | 271 | 19 × 14 | 2 G 3 ,, 6 ,, ,, | 2505·78 | 2004·62 |
| G 3 C 6 | 394 | 19 × 20 | 3 G 3 ,, 6 ,, ,, | 3618·67 | 2894·83 |
| G 5 C 1 | 77 | 16 × 10 | 1 G 5 ,, 2 ,, ,, | 618·85 | 495·08 |
| G 5 C 2 | 127 | 16 × 12 | 2 G 5 ,, 2 ,, ,, | 907·03 | 725·62 |
| G 5 C 3 | 191 | 16 × 18 | 3 G 5 ,, 2 ,, ,, | 1360·55 | 1088·44 |
| G 5 C 4 | 111½ | 17 × 10 | 1 G 5 ,, 4 ,, ,, | 1014·83 | 811·86 |
| G 5 C 5 | 210 | 18 × 12 | 2 G 5 ,, 6 ,, ,, | 1813·7 | 1450·96 |
| G 5 C 6 | 315 | 18 × 18 | 3 G 5 ,, 6 ,, ,, | 2720·55 | 2176·44 |
| G 6 C 1 | 142 | 14½ × 15 | 2 G 6 ,, 1 ,, ,, | 898·33 | 718·66 |
| G 6 C 2 | 93 | 15 × 10 | 1 G 6 ,, 2 ,, ,, | 684·77 | 547·81 |
| G 6 C 3 | 164 | 15 × 14 | 2 G 6 ,, 2 ,, ,, | 1137·54 | 910·03 |
| G 6 C 4 | 245 | 15 × 20 | 3 G 6 ,, 2 ,, ,, | 1667·64 | 1334·11 |
| G 6 C 5 | 127 | 16 × 10 | 1 G 6 ,, 4 ,, ,, | 1056·77 | 845·41 |
| G 6 C 6 | 212 | 16 × 14 | 2 G 6 ,, 4 ,, ,, | 1633·54 | 1306·83 |
| G 6 C 7 | 326 | 16 × 20 | 3 G 6 ,, 4 ,, ,, | 2370·31 | 1896·24 |
| G 8 C 1 | 50½ | 12⅜ × 8 | 1 G 8 and 1 ⅜-in. plates | 257·83 | 206·26 |
| G 8 C 2 | 96 | 12⅜ × 12 | 2 G 8 ,, 1 ,, ,, | 485·9 | 388·72 |
| G 8 C 3 | 141 | 12⅜ × 16 | 3 G 8 ,, 1 ,, ,, | 713·78 | 571·02 |
| G 8 C 4 | 75 | 13 × 10 | 1 G 8 and 2 ½-in. plates | 500·49 | 400·39 |
| G 8 C 5 | 121 | 13 × 12 | 2 G 8 ,, 2 ,, ,, | 734·31 | 587·44 |
| G 8 C 6 | 182 | 13 × 18 | 3 G 8 ,, 2 ,, ,, | 1101·47 | 881·17 |
| G 8 C 7 | 108 | 14 × 10 | 1 G 8 ,, 4 ,, ,, | 831·24 | 664·99 |
| G 8 C 8 | 162 | 14 × 12 | 2 G 8 ,, 4 ,, ,, | 1107·81 | 886·24 |
| G 8 C 9 | 244 | 14 × 18 | 3 G 8 ,, 4 ,, ,, | 1661·72 | 1329·37 |
| G 10 C 1 | 46½ | 10⅜ × 8 | 1 G 10 and 1 ⅜-in. plates | 187·94 | 150·35 |
| G 10 C 2 | 87 | 10⅜ × 12 | 2 G 10 ,, 1 ,, ,, | 367·66 | 294·15 |
| G 10 C 3 | 56½ | 10¾ × 8 | 1 G 10 ,, 2 ,, ,, | 295·34 | 236·27 |
| G 10 C 4 | 103 | 10¾ × 12 | 2 G 10 ,, 2 ,, ,, | 507·64 | 406·11 |
| G 10 C 5 | 170 | 11 × 18 | 3 G 10 ,, 2 ½-in. plates | 874·35 | 699·48 |
| G 10 C 6 | 76½ | 11½ × 8 | 1 G 10 ,, 4 ⅜-in. plates | 455·26 | 364·21 |
| G 10 C 7 | 134 | 11½ × 12 | 2 G 10 ,, 4 ,, ,, | 738·52 | 590·81 |
| G 10 C 8 | 231 | 12 × 18 | 3 G 10 ,, 4 ½-in. plates | 1351·6 | 1081·28 |

### TABLE 142.—BULB TEES (STEEL).

(Dorman, Long & Co., Limited.)

| Depth (Web). | Width of Flange. | Web Thickness. | Flange Thickness. | Depth (Web). | Width of Flange. | Web Thickness. | Flange Thickness. |
|---|---|---|---|---|---|---|---|
| Inches. | Inches. | Inch. | Inch. | Inches. | Inches. | Inch. | Inch. |
| 12 | $6\frac{1}{2}$ | $\frac{11}{20}$ to $\frac{14}{20}$ | $\frac{11}{20}$ | $8\frac{1}{2}$ | $5\frac{1}{4}$ | $\frac{8}{20}$ to $\frac{10}{20}$ | $\frac{8}{20}$ |
| 11 | $6\frac{1}{2}$ | $\frac{10}{20}$ to $\frac{13}{20}$ | $\frac{10}{20}$ | 8 | 5 | $\frac{8}{20}$ & $\frac{9}{20}$ | $\frac{8}{20}$ |
| 10 | 6 | $\frac{10}{20}$ to $\frac{12}{20}$ | $\frac{9}{20}$ | 7 | 5 | $\frac{8}{20}$ & $\frac{10}{20}$ | $\frac{8}{20}$ |
| 9 | $5\frac{1}{2}$ | $\frac{9}{20}$ & $\frac{11}{20}$ | $\frac{9}{20}$ | 6 | $4\frac{1}{2}$ | $\frac{8}{20}$ & $\frac{10}{20}$ | $\frac{8}{20}$ |

## BOLTS AND NUTS.

### Screw Bolts and Nuts.

According to the Whitworth system of standard sizes of bolts and nuts, the thickness of the bolt-head is $\frac{7}{8}$ths of the diameter, and that of the nut is equal to the diameter. The angle formed by the two sides of the triangular thread is 55 degrees. The top and the bottom of the thread are rounded, each to the extent of one-sixth of the nominal height of the thread, and the actual height of the thread is about 63 per cent. of the pitch. For screws with square threads, the number of threads per inch is one half of the number for triangular threads.

The dimensions of bolts and nuts for triangular threads are given in Table 143.

In the Sellers or Franklin Institute (U.S.A.) system of screw threads, the angle of the triangular thread is 60 degrees. The top of the thread is flattened, and there is a flat interspace at the base of the thread. The head and nuts are hexagonal. The thicknesses of heads and nuts are equal to 1 diameter minus $\frac{1}{16}$th inch. The breadth across the flats is equal to $1\frac{1}{2}$ diameters plus $\frac{1}{16}$ inch.

Dimensions are given in Table 144.

TABLE 143.—WHITWORTH STANDARD SCREW BOLTS AND NUTS.

*Threads triangular in section; Heads and Nuts hexagonal.*

| Screw. | | | Head and Nut, Hexagonal. | | |
|---|---|---|---|---|---|
| Diameter of Bolt and Screw. | Diameter at Bottom of Thread. | Threads per Inch. | Thickness of Head. | Thickness of Nut. | Breadth across the Flats. |
| Inches. | Inches. | Threads. | Inches. | Inches. | Inches. |
| $\frac{1}{16}$ | ... | 60 | ... | ... | ... |
| $\frac{3}{32}$ | ... | 48 | ... | ... | ... |
| $\frac{1}{8}$ | ·093 | 40 | ·109 | $\frac{1}{8}$ | ·338 |
| $\frac{5}{32}$ | ... | 32 | ... | ... | ... |
| $\frac{3}{16}$ | ·134 | 24 | ·164 | $\frac{3}{16}$ | ·448 |
| $\frac{7}{32}$ | ... | 24 | ... | ... | ... |
| $\frac{1}{4}$ | ·186 | 20 | ·219 | $\frac{1}{4}$ | ·525 |
| $\frac{5}{16}$ | ·241 | 18 | ·273 | $\frac{5}{16}$ | ·601 |
| $\frac{3}{8}$ | ·295 | 16 | ·328 | $\frac{3}{8}$ | ·709 |
| $\frac{7}{16}$ | ·346 | 14 | ·383 | $\frac{7}{16}$ | ·820 |
| $\frac{1}{2}$ | ·393 | 12 | ·437 | $\frac{1}{2}$ | ·919 |
| $\frac{9}{16}$ | ·456 | 12 | ·492 | $\frac{9}{16}$ | 1·011 |
| $\frac{5}{8}$ | ·508 | 11 | ·547 | $\frac{5}{8}$ | 1·101 |
| $\frac{11}{16}$ | ·571 | 11 | ·601 | $\frac{11}{16}$ | 1·201 |
| $\frac{3}{4}$ | ·622 | 10 | ·656 | $\frac{3}{4}$ | 1·301 |
| $\frac{13}{16}$ | ·684 | 10 | ·711 | $\frac{13}{16}$ | 1·39 |
| $\frac{7}{8}$ | ·733 | 9 | ·766 | $\frac{7}{8}$ | 1·479 |
| $\frac{15}{16}$ | ·795 | 9 | ·820 | $\frac{15}{16}$ | 1·574 |
| 1 | ·840 | 8 | ·875 | 1 | 1·670 |
| $1\frac{1}{8}$ | ·942 | 7 | ·984 | $1\frac{1}{8}$ | 1·860 |
| $1\frac{1}{4}$ | 1·067 | 7 | 1·094 | $1\frac{1}{4}$ | 2·048 |
| $1\frac{3}{8}$ | 1·161 | 6 | 1·203 | $1\frac{3}{8}$ | 2·215 |
| $1\frac{1}{2}$ | 1·286 | 6 | 1·312 | $1\frac{1}{2}$ | 2·413 |
| $1\frac{5}{8}$ | 1·369 | 5 | 1·422 | $1\frac{5}{8}$ | 2·576 |
| $1\frac{3}{4}$ | 1·494 | 5 | 1·531 | $1\frac{3}{4}$ | 2·758 |
| $1\frac{7}{8}$ | 1·590 | $4\frac{1}{2}$ | 1·641 | $1\frac{7}{8}$ | 3·018 |
| 2 | 1·715 | $4\frac{1}{2}$ | 1·75 | 2 | 3·149 |
| $2\frac{1}{8}$ | 1·840 | $4\frac{1}{2}$ | 1·859 | $2\frac{1}{8}$ | 3·337 |
| $2\frac{1}{4}$ | 1·930 | 4 | 1·969 | $2\frac{1}{4}$ | 3·546 |
| $2\frac{3}{8}$ | 2·055 | 4 | 2·078 | $2\frac{3}{8}$ | 3·75 |
| $2\frac{1}{2}$ | 2·180 | 4 | 2·187 | $2\frac{1}{2}$ | 3·894 |
| $2\frac{5}{8}$ | 2·305 | 4 | 2·297 | $2\frac{5}{8}$ | 4·049 |
| $2\frac{3}{4}$ | 2·384 | $3\frac{1}{2}$ | 2·406 | $2\frac{3}{4}$ | 4·181 |
| $2\frac{7}{8}$ | 2·509 | $3\frac{1}{2}$ | 2·516 | $2\frac{7}{8}$ | 4·346 |
| 3 | 2·634 | $3\frac{1}{2}$ | 2·625 | 3 | 4·531 |
| $3\frac{1}{4}$ | ... | $3\frac{1}{4}$ | ... | ... | ... |
| $3\frac{1}{2}$ | ... | $3\frac{1}{4}$ | ... | ... | ... |
| $3\frac{3}{4}$ | ... | 3 | ... | ... | ... |

TABLE 143.—WHITWORTH SCREW BOLTS, ETC. (*continued*).

| Screw. | | | Head and Nut, Hexagonal. | | |
|---|---|---|---|---|---|
| Diameter of Bolt and Screw. | Diameter at Bottom of Thread. | Threads per Inch. | Thickness of Head. | Thickness of Nut. | Breadth across the Flats. |
| Inches. | Inches. | Threads. | Inches. | Inches. | Inches. |
| 4 | ... | 3 | ... | ... | ... |
| $4\frac{1}{4}$ | ... | $2\frac{7}{8}$ | ... | ... | ... |
| $4\frac{1}{2}$ | ... | $2\frac{7}{8}$ | ... | ... | ... |
| $4\frac{3}{4}$ | ... | $2\frac{3}{4}$ | ... | ... | ... |
| 5 | ... | $2\frac{3}{4}$ | ... | ... | ... |
| $5\frac{1}{4}$ | ... | $2\frac{5}{8}$ | ... | ... | ... |
| $5\frac{1}{2}$ | ... | $2\frac{5}{8}$ | ... | ... | ... |
| $5\frac{3}{4}$ | ... | $2\frac{1}{2}$ | ... | ... | ... |
| 6 | ... | $2\frac{1}{2}$ | ... | ... | ... |

TABLE 144.—SELLERS OR FRANKLIN INSTITUTE STANDARD SCREW BOLTS AND NUTS.

*Threads triangular in section; heads and nuts hexagonal.*

| Diameter of Bolt and Screw. | Diameter at Bottom of Thread. | Width of Flat Summits and Base of Thread. | Threads per Inch. | Diameter of Bolt and Screw. | Diameter at Bottom of Thread. | Width of Flat Summits and Base of Thread. | Threads per Inch. |
|---|---|---|---|---|---|---|---|
| Inches. | Inches. | Inch. | Thre'ds. | Inches. | Inches. | Inch. | Thre'ds. |
| $\frac{1}{4}$ | ·185 | ·0062 | 20 | 2 | 1·712 | ·0277 | $4\frac{1}{2}$ |
| $\frac{5}{16}$ | ·240 | ·0074 | 18 | $2\frac{1}{4}$ | 1·962 | ·0277 | $4\frac{1}{2}$ |
| $\frac{3}{8}$ | ·294 | ·0078 | 16 | $2\frac{1}{2}$ | 2·176 | ·0312 | 4 |
| $\frac{7}{16}$ | ·344 | ·0089 | 14 | $2\frac{3}{4}$ | 2·426 | ·0312 | 4 |
| $\frac{1}{2}$ | ·400 | ·0096 | 13 | 3 | 2·629 | ·0357 | $3\frac{1}{2}$ |
| $\frac{9}{16}$ | ·454 | ·0104 | 12 | $3\frac{1}{4}$ | 2·879 | ·0357 | $3\frac{1}{2}$ |
| $\frac{5}{8}$ | ·507 | ·0113 | 11 | $3\frac{1}{2}$ | 3·100 | ·0384 | $3\frac{1}{4}$ |
| $\frac{3}{4}$ | ·620 | ·0125 | 10 | $3\frac{3}{4}$ | 3·317 | ·0413 | 3 |
| $\frac{7}{8}$ | ·731 | ·0138 | 9 | 4 | 3·567 | ·0413 | 3 |
| 1 | ·837 | ·0156 | 8 | $4\frac{1}{4}$ | 3·798 | ·0435 | $2\frac{7}{8}$ |
| $1\frac{1}{8}$ | ·940 | ·0178 | 7 | $4\frac{1}{2}$ | 4·028 | ·0454 | $2\frac{3}{4}$ |
| $1\frac{1}{4}$ | 1·065 | ·0178 | 7 | $4\frac{3}{4}$ | 4·256 | ·0476 | $2\frac{5}{8}$ |
| $1\frac{3}{8}$ | 1·160 | ·0208 | 6 | 5 | 4·480 | ·0500 | $2\frac{1}{2}$ |
| $1\frac{1}{2}$ | 1·284 | ·0208 | 6 | $5\frac{1}{4}$ | 4·730 | ·0500 | $2\frac{1}{2}$ |
| $1\frac{5}{8}$ | 1·389 | ·0227 | $5\frac{1}{2}$ | $5\frac{1}{2}$ | 4·953 | ·0526 | $2\frac{3}{8}$ |
| $1\frac{3}{4}$ | 1·491 | ·0250 | 5 | $5\frac{3}{4}$ | 5·203 | ·0526 | $2\frac{3}{8}$ |
| $1\frac{7}{8}$ | 1·616 | ·0250 | 5 | 6 | 5·423 | ·0555 | $2\frac{1}{4}$ |

*Note* 1.—The breadth of heads and nuts, across the flats, is equal to $1\frac{1}{2}$ diameters + $\frac{1}{16}$ inch.

*Note* 2.—The thicknesses of the head and the nut are equal diameter − $\frac{1}{16}$ inch.

TABLE 145.—WHITWORTH'S STANDARD PITCHES OF THREAD FOR SCREWED IRON PIPING.

| Diameter. | Threads per Inch. | Diameter. | Threads per Inch. | Diameter. | Threads per Inch. |
|---|---|---|---|---|---|
| Inches. | Threads. | Inches. | Threads. | Inches. | Threads. |
| $\frac{1}{8}$ | 28 | $\frac{5}{8}$ | 14 | $1\frac{1}{2}$ | 11 |
| $\frac{1}{4}$ | 19 | $\frac{3}{4}$ | 14 | $1\frac{3}{4}$ | 11 |
| $\frac{3}{8}$ | 19 | 1 | 11 | 2 | 11 |
| $\frac{1}{2}$ | 14 | $1\frac{1}{4}$ | 11 | above 2 | 11 |

TABLE 146.—FRENCH STANDARD BOLTS AND NUTS WITH HEXAGONAL HEADS AND NUTS.

(Armengaud).

1. TRIANGULAR THREAD (Equilateral Triangle).

| Screw. | | | | Head and Nut. | | | Working Tensile Stress. |
|---|---|---|---|---|---|---|---|
| Diameter of Bolt and Screw. | | Diameter at Bottom of Thread. | Number of Threads per Inch. | Thickness of Head. | Thickness of Nut. | Breadth across the Flats. | |
| Millimetres. | Inches. | Inches. | Threads. | Inches. | Inches. | Inches. | Lbs. |
| 5 | ·20 | ·13 | 18·1 | ·24 | ·20 | ·55 | 44 |
| 7·5 | ·30 | ·22 | 16 | ·30 | ·30 | ·68 | 99 |
| 10 | ·39 | ·31 | 14·1 | ·38 | ·39 | ·88 | 178 |
| 12·5 | ·49 | ·39 | 12·7 | ·44 | ·49 | 1·04 | 277 |
| 15 | ·59 | ·48 | 11·5 | ·52 | ·59 | 1·20 | 400 |
| 17·5 | ·69 | ·58 | 10·6 | ·58 | ·69 | 1·40 | 545 |
| 20 | ·79 | ·66 | 9·8 | ·66 | ·79 | 1·50 | 713 |
| 22·5 | ·89 | ·76 | 9·1 | ·72 | ·89 | 1·68 | 902 |
| | | | | | | | Tons. |
| 25 | ·98 | ·84 | 8·5 | ·80 | ·98 | 1·84 | ·50 |
| 30 | 1·18 | 1·02 | 7·5 | ·94 | 1·18 | 2·16 | ·73 |
| 35 | 1·38 | 1·20 | 6·7 | 1·08 | 1·38 | 2·48 | ·99 |
| 40 | 1·58 | 1·40 | 6·0 | 1·22 | 1·58 | 2·80 | 1·30 |
| 45 | 1·77 | 1·56 | 5·5 | 1·36 | 1·77 | 3·20 | 1·64 |
| 50 | 1·97 | 1·74 | 5·1 | 1·50 | 1·97 | 3·44 | 2·03 |
| 55 | 2·17 | 1·92 | 4·7 | 1·64 | 2·17 | 3·76 | 2·45 |
| 60 | 2·36 | 2·08 | 4·4 | 1·74 | 2·36 | 4·08 | 2·92 |
| 65 | 2·56 | 2·26 | 4·1 | 1·92 | 2·56 | 4·40 | 3·42 |
| 70 | 2·76 | 2·44 | 3·8 | 2·06 | 2·76 | 4·70 | 3·97 |
| 75 | 2·95 | 2·60 | 3·5 | 2·20 | 2·95 | 5·00 | 4·56 |
| 80 | 3·15 | 2·78 | 3·4 | 2·34 | 3·15 | 5·35 | 5·12 |

TABLE 146.—FRENCH STANDARD BOLTS AND NUTS (*cont.*).

2. SQUARE THREAD.

| Screw. | | | | Head and Nut. | | | Working Tensile Stress. |
|---|---|---|---|---|---|---|---|
| Diameter of Bolt and Screw. | | Depth of Thread. | Number of Threads per Inch. | Thickness of Head. | Thickness of Nut. | Breadth across the Flats. | |
| Millimetres. | Inches. | Inches. | Threads. | Inches. | Inches. | Inches. | Tons. |
| 20 | ·79 | ·072 | 6·57 | ... | 1·82 | ... | ·32 |
| 25 | ·98 | ·081 | 5·97 | ... | 2·01 | ... | ·51 |
| 30 | 1·18 | ·093 | 5·40 | ... | 2·22 | ... | ·73 |
| 35 | 1·38 | ·10 | 4·93 | ... | 2·41 | ... | ·99 |
| 40 | 1·57 | ·106 | 4·53 | ... | 2·63 | ... | 1·30 |
| 45 | 1·77 | ·114 | 4·20 | ... | 2·85 | ... | 1·64 |
| 50 | 1·97 | ·128 | 3·91 | ... | 3·07 | ... | 2·03 |
| 55 | 2·17 | ·13 | 3·65 | ... | 3·30 | ... | 2·45 |
| 60 | 2·36 | ·14 | 3·43 | ... | 3·50 | ... | 2·92 |
| 65 | 2·56 | ·15 | 3·23 | ... | 3·70 | ... | 3·42 |
| 70 | 2·76 | ·158 | 3·06 | ... | 3·92 | ... | 3·97 |
| 75 | 2·95 | ·166 | 2·92 | ... | 4·13 | ... | 4·56 |
| 80 | 3·15 | ·174 | 2·76 | ... | 4·36 | ... | 5·18 |
| 85 | 3·35 | ·183 | 2·63 | ... | 4·58 | ... | 5·85 |
| 90 | 3·54 | ·192 | 2·51 | ... | 4·78 | ... | 6·56 |
| 95 | 3·74 | ·200 | 2·41 | ... | 5·00 | ... | 7·30 |
| 100 | 3·94 | ·209 | 2·31 | ... | 5·22 | ... | 8·10 |
| 105 | 4·13 | ·220 | 2·22 | ... | 5·43 | ... | 8·93 |
| 110 | 4·33 | ·226 | 2·13 | ... | 5·66 | ... | 9·80 |
| 115 | 4·53 | ·230 | 2·06 | ... | 5·87 | ... | 10·71 |
| 120 | 4·72 | ·234 | 2·00 | ... | 6·08 | ... | 11·66 |

TABLE 147.—IRON WASHERS.

| Diameters. | | Thickness. | Number per Pound. | Diameters. | | Thickness. | Number per Pound. |
|---|---|---|---|---|---|---|---|
| Washer. | Bolt Hole. | | | Washer. | Bolt Hole. | | |
| Inches. | Inches. | B.W.G. | Washers. | Inches. | Inches. | B.W.G. | Washers. |
| $\frac{1}{2}$ | $\frac{1}{4}$ | 18 | 543 | $1\frac{3}{4}$ | $\frac{11}{16}$ | 10 | 17·0 |
| $\frac{5}{8}$ | $\frac{5}{16}$ | 16 | 228 | 2 | $\frac{13}{16}$ | 10 | 10·7 |
| $\frac{3}{4}$ | $\frac{5}{16}$ | 16 | 147 | $2\frac{1}{4}$ | $\frac{15}{16}$ | 9 | 8·7 |
| $\frac{7}{8}$ | $\frac{3}{8}$ | 16 | 123 | $2\frac{1}{2}$ | $1\frac{1}{16}$ | 9 | 6·3 |
| 1 | $\frac{7}{16}$ | 14 | 70·0 | $2\frac{3}{4}$ | $1\frac{1}{4}$ | 9 | 4·7 |
| $1\frac{1}{4}$ | $\frac{1}{2}$ | 14 | 50·0 | 3 | $1\frac{3}{8}$ | 9 | 3·7 |
| $1\frac{3}{8}$ | $\frac{9}{16}$ | 12 | 30·0 | $3\frac{1}{2}$ | $1\frac{1}{2}$ | 9 | 3·0 |
| $1\frac{1}{2}$ | $\frac{5}{8}$ | 12 | 25·7 | | | | |

TABLE 148.—WEIGHTS OF 100 HEXAGONAL HEAD BOLTS AND NUTS.

| Length under Head. | Diameter of Bolts. | | | | | | |
|---|---|---|---|---|---|---|---|
| | ¼ in. | ⅜ in. | ½ in. | ⅝ in. | ¾ in. | ⅞ in. | 1 in. |
| Inches. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. |
| 1 | 3⅛ | 7¾ | 16⅜ | 26¾ | ... | ... | ... |
| 1¼ | 3½ | 8⅝ | 17⅜ | 29¼ | ... | ... | ... |
| 1½ | 3⅞ | 9½ | 18⅜ | 31¾ | ... | ... | ... |
| 1¾ | 4¼ | 10⅜ | 19⅜ | 34¼ | ... | ... | ... |
| 2 | 4⅝ | 11¼ | 20⅜ | 36¾ | 58 | 115 | 159 |
| 2¼ | 5 | 12¼ | 21⅞ | 39¼ | 61½ | 117½ | 164 |
| 2½ | 5⅜ | 13⅛ | 23⅜ | 41¾ | 65 | 120 | 169 |
| 2¾ | 5¾ | 14 | 24⅞ | 44¼ | 68½ | 122½ | 174 |
| 3 | 6⅛ | 15 | 26⅜ | 46¾ | 72 | 125 | 179 |
| 3½ | 6¾ | 16⅞ | 29⅜ | 51¼ | 78 | 133 | 189 |
| 4 | 7⅜ | 18⅞ | 32⅜ | 55¾ | 84 | 141 | 199 |
| 4½ | 8 | 20⅜ | 35⅜ | 60¼ | 89½ | 149 | 209 |
| 5 | 8⅝ | 22 | 38⅜ | 64¾ | 95 | 157 | 219 |
| 5½ | 9⅜ | 23⅝ | 41⅜ | 68¾ | 100½ | 165 | 230 |
| 6 | 10 | 25¼ | 44⅜ | 72¾ | 106 | 173 | 241 |
| 7 | 11⅜ | 28¼ | 50⅜ | 80¾ | 118 | 189 | 263 |
| 8 | 12¾ | 31¾ | 56⅜ | 88¾ | 131 | 205 | 285 |
| 9 | 14⅛ | 34¾ | 62⅜ | 96¾ | 144 | 221 | 307 |
| 10 | 15⅝ | 38¾ | 68⅜ | 104¾ | 158 | 237 | 329 |
| 11 | 16⅞ | 41⅜ | 74⅜ | 112⅞ | 173 | 253 | 351 |
| 12 | 18¼ | 44¾ | 80⅜ | 121½ | 188 | 269 | 372 |

TABLE 149.—WEIGHTS OF 100 SQUARE-HEAD BOLTS AND NUTS.

| Length under Head. | Diameter of Bolts. | | | | | | |
|---|---|---|---|---|---|---|---|
| | ¼ in. | ⅜ in. | ½ in. | ⅝ in. | ¾ in. | ⅞ in. | 1 in. |
| Inches. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. |
| 1 | 3½ | 9 | 20 | 32 | ... | ... | ... |
| 1¼ | 3⅞ | 9⅞ | 21 | 34½ | ... | ... | ... |
| 1½ | 4¼ | 10¾ | 22 | 37 | ... | ... | ... |
| 1¾ | 4⅝ | 11⅝ | 23 | 39½ | ... | ... | ... |
| 2 | 5 | 12½ | 24 | 42 | 70 | 130 | 180 |
| 2¼ | 5⅜ | 13½ | 25½ | 44½ | 73½ | 132½ | 185 |
| 2½ | 5¾ | 14⅜ | 27 | 47 | 77 | 135 | 190 |

TABLE 149.—WEIGHT OF 100 SQUARE-HEAD BOLTS AND NUTS (*continued*).

| Length under Head. | Diameter of Bolts. | | | | | | |
|---|---|---|---|---|---|---|---|
| | $\frac{1}{4}$ in. | $\frac{3}{8}$ in. | $\frac{1}{2}$ in. | $\frac{5}{8}$ in. | $\frac{3}{4}$ in. | $\frac{7}{8}$ in. | 1 in. |
| Inches. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. |
| $2\frac{3}{4}$ | $6\frac{1}{8}$ | $15\frac{1}{2}$ | $28\frac{1}{2}$ | $49\frac{1}{2}$ | $80\frac{1}{2}$ | $137\frac{1}{2}$ | 195 |
| 3 | $6\frac{1}{2}$ | $16\frac{1}{4}$ | 30 | 52 | 84 | 140 | 200 |
| $3\frac{1}{2}$ | $7\frac{1}{8}$ | $18\frac{1}{8}$ | 33 | $56\frac{1}{2}$ | 90 | 148 | 210 |
| 4 | $7\frac{3}{4}$ | 20 | 36 | 61 | 96 | 156 | 220 |
| $4\frac{1}{2}$ | $8\frac{3}{8}$ | $21\frac{5}{8}$ | 39 | $65\frac{1}{2}$ | $101\frac{1}{2}$ | 164 | 230 |
| 5 | 9 | $23\frac{1}{4}$ | 42 | 70 | 107 | 172 | 240 |
| $5\frac{1}{2}$ | $9\frac{3}{4}$ | $24\frac{7}{8}$ | 45 | 74 | $112\frac{1}{2}$ | 180 | 251 |
| 6 | $10\frac{3}{8}$ | $26\frac{1}{2}$ | 48 | 78 | 118 | 188 | 262 |
| 7 | $11\frac{3}{4}$ | $29\frac{1}{2}$ | 54 | 86 | 130 | 204 | 284 |
| 8 | $13\frac{1}{8}$ | 33 | 60 | 94 | 143 | 220 | 306 |
| 9 | $14\frac{1}{2}$ | 36 | 66 | 102 | 156 | 236 | 328 |
| 10 | 16 | 40 | 72 | 110 | 170 | 252 | 350 |
| 11 | $17\frac{1}{4}$ | 43 | 78 | 118 | 185 | 268 | 372 |
| 12 | $18\frac{5}{8}$ | 46 | 84 | 127 | 200 | 284 | 393 |

TABLE 150.—WEIGHT AND TENSILE STRENGTH OF ORDINARY IRON BOLTS.

(Chapman.)

| Ends Enlarged, or Upset. | | | | Ends not Enlarged. | |
|---|---|---|---|---|---|
| Diameter of Shank. | Weight per Lineal Foot. | Breaking Stress. | Breaking Stress. | Diameter of Shank. | Weight per Lineal Foot. |
| Inches. | Pounds. | Tons. | Pounds. | Inches. | Pounds. |
| $\frac{1}{8}$ | ·0414 | ·245 | 549 | ... | ... |
| $\frac{3}{16}$ | ·093 | ·553 | 1,239 | ... | ... |
| $\frac{1}{4}$ | ·165 | ·983 | 2,202 | ·35 | ·321 |
| $\frac{5}{16}$ | ·258 | 1·53 | 3,427 | ·43 | ·452 |
| $\frac{3}{8}$ | ·372 | 2·21 | 4,950 | ·50 | ·654 |
| $\frac{7}{16}$ | ·506 | 3·00 | 6,720 | ·58 | ·897 |
| $\frac{1}{2}$ | ·661 | 3·93 | 8,803 | ·66 | 1·14 |
| $\frac{9}{16}$ | ·837 | 4·97 | 11,133 | ·73 | 1·41 |
| $\frac{5}{8}$ | 1·03 | 6·14 | 13,754 | ·80 | 1·67 |
| $\frac{11}{16}$ | 1·25 | 7·42 | 16,621 | ·88 | 2·03 |
| $\frac{3}{4}$ | 1·49 | 8·83 | 19,779 | ·96 | 2·41 |
| $\frac{13}{16}$ | 1·75 | 10·4 | 23,296 | 1·04 | 2·81 |

TABLE 150.—WEIGHT AND STRENGTH OF IRON BOLTS (*con.*).

| Ends Enlarged, or Upset. | | | | Ends not Enlarged. | |
|---|---|---|---|---|---|
| Diameter of Shank. | Weight per Lineal Foot. | Breaking Stress. | Breaking Stress. | Diameter of Shank. | Weight per Lineal Foot. |
| Inches. | Pounds. | Tons. | Pounds. | Inches. | Pounds. |
| $\frac{7}{8}$ | 2·03 | 12·0 | 26,880 | 1·12 | 3·26 |
| $\frac{15}{16}$ | 2·33 | 13·8 | 30,012 | 1·20 | 3·77 |
| 1 | 2·65 | 15·7 | 35,168 | 1·27 | 4·27 |
| $1\frac{1}{16}$ | 2·99 | 16·8 | 37,632 | 1·35 | 4·77 |
| $1\frac{1}{8}$ | 3·35 | 18·9 | 42,336 | 1·42 | 5·28 |
| $1\frac{3}{16}$ | 3·73 | 21·1 | 47,264 | 1·49 | 5·81 |
| $1\frac{1}{4}$ | 4·13 | 23·3 | 52,192 | 1·55 | 6·39 |
| $1\frac{5}{16}$ | 4·56 | 25·7 | 57,568 | 1·64 | 7·04 |
| $1\frac{3}{8}$ | 5·00 | 28·2 | 63,168 | 1·72 | 7·74 |
| $1\frac{7}{16}$ | 5·47 | 30·8 | 68,992 | 1·80 | 8·48 |
| $1\frac{1}{2}$ | 5·95 | 33·6 | 75,264 | 1·87 | 9·20 |
| $1\frac{9}{16}$ | 6·46 | 36·4 | 81,536 | 1·94 | 9·88 |
| $1\frac{5}{8}$ | 6·99 | 39·4 | 88,256 | 2·00 | 10·6 |
| $1\frac{11}{16}$ | 7·53 | 42·5 | 95,200 | 2·07 | 11·3 |
| $1\frac{3}{4}$ | 8·10 | 45·7 | 102,368 | 2·14 | 12·0 |
| $1\frac{13}{16}$ | 8·69 | 49·0 | 109,760 | 2·22 | 12·9 |
| $1\frac{7}{8}$ | 9·30 | 52·5 | 117,600 | 2·30 | 13·8 |
| $1\frac{15}{16}$ | 9·93 | 56·0 | 125,440 | 2·38 | 14·7 |
| 2 | 10·6 | 59·7 | 133,728 | 2·45 | 15·7 |
| $2\frac{1}{8}$ | 12·0 | 63·8 | 142,912 | 2·59 | 17·5 |
| $2\frac{1}{4}$ | 13·4 | 71·6 | 160,384 | 2·73 | 19·5 |
| $2\frac{3}{8}$ | 14·9 | 79·7 | 178,528 | 2·88 | 21·6 |
| $2\frac{1}{2}$ | 16·5 | 88·4 | 198,016 | 3·02 | 23·9 |
| $2\frac{5}{8}$ | 18·2 | 97·4 | 218,176 | 3·16 | 26·1 |
| $2\frac{3}{4}$ | 20·0 | 106·9 | 239,456 | 3·30 | 28·5 |
| $2\frac{7}{8}$ | 21·9 | 116·8 | 261,632 | 3·45 | 31·1 |
| 3 | 23·8 | 127·2 | 284,928 | 3·60 | 33·9 |
| $3\frac{1}{4}$ | 27·9 | 141·0 | 315,840 | 3·86 | 39·1 |
| $3\frac{1}{2}$ | 32·4 | 163·6 | 366,464 | 4·12 | 44·4 |
| $3\frac{3}{4}$ | 37·2 | 187·7 | 420,448 | 4·41 | 51·0 |
| 4 | 42·3 | 213·6 | 478,464 | 4·70 | 57·8 |
| $4\frac{1}{4}$ | 47·8 | 227·0 | 508,480 | 4·98 | 65·2 |
| $4\frac{1}{2}$ | 53·6 | 254·5 | 570,080 | 5·25 | 72·9 |
| $4\frac{3}{4}$ | 59·7 | 283·5 | 635,040 | 5·53 | 80·5 |
| 5 | 66·1 | 314·2 | 703,808 | 5·80 | 88·1 |
| $5\frac{1}{4}$ | 72·9 | 324·7 | 727,328 | 6·08 | 97·0 |
| $5\frac{1}{2}$ | 80·0 | 356·4 | 798,336 | 6·36 | 106 |
| $5\frac{3}{4}$ | 87·5 | 389·5 | 872,480 | 6·63 | 116 |
| 6 | 95·2 | 424·1 | 949,984 | 6·90 | 126 |

## Table 151.—Nails, Iron or Steel : Sizes and Weights.

| Description. | Length. In. | Weight per 1,000. Lb. | Oz. | Description. | Length. In. | Weight per 1,000. Lb. | Oz. |
|---|---|---|---|---|---|---|---|
| Spike, die heads, flat points, wrought | 1½ | 4 | 0 | Clasp, fine, wrought | 3 | 11 | 0 |
| | 2 | 7 | 4 | ” | 4 | ... | |
| | 2½ | 12 | 8 | Clasp, fine, cut . . | 2 | 6 | 0 |
| ” | 3 | 19 | 12 | ” | 2½ | 10 | 0 |
| ” | 3½ | 27 | 4 | ” | 3 | 16 | 0 |
| ” | 4 | 42 | 8 | Clasp, strong . . | 1¾ | 7 | 0 |
| ” | 5 | 89 | 8 | ” . . | 2¼ | 10 | 0 |
| ” | 6 | 153 | 12 | ” . . | 2½ | 12 | 0 |
| ” | 7 | 241 | 0 | ” . . | 2¾ | 14 | 0 |
| Spike, square head, flat points, wrought | 6 | 263 | 0 | ” . . | 3⅛ | 20 | 0 |
| | 7 | 361 | 12 | ” . . | 3⅜ | 25 | 0 |
| | 8 | 478 | 12 | ” . . | 3¾ | 32 | 0 |
| ” | 9 | 596 | 0 | ” . . | 4 | 40 | 0 |
| ” | 10 | 707 | 8 | Clout, countersunk, fine, wrought . . | 1 | 4 | 12 |
| ” | 12 | 998 | 0 | | 1½ | 9 | 0 |
| Rose, sharp points, wrought | 1 | 2 | 9 | | 2 | 19 | 0 |
| | | | | ” | 3 | 44 | 0 |
| Rose, fine flat points, wrought | 1¼ | 5 | 0 | Clout, countersunk, strong, wrought . . | 1½ | 14 | 8 |
| | 1½ | 4 | 0 | | 2 | 25 | 8 |
| ” | 2 | 7 | 12 | | 2½ | 43 | 8 |
| Rose, fine flat points, strong . | 2½ | 18 | 8 | ” | 3½ | 82 | 0 |
| | 3 | 28 | 12 | Clout, strong, wrought . . | ¾ | 2 | 0 |
| ” | 3½ | 40 | 0 | | 1 | 3 | 0 |
| ” | 4 | 54 | 4 | ” | 1¼ | 5 | 0 |
| ” | 4½ | 74 | 8 | ” | 1½ | 7 | 0 |
| ” | 5 | 92 | 8 | ” | 2 | 13 | 0 |
| Rose, fine flat points, stamped | 1¼ | 4 | 0 | Brads, fine, billed, wrought . . | ½ | 0 | 4 |
| | 1½ | 5 | 0 | | ¾ | 0 | 10 |
| ” | 2 | 7 | 0 | ” | 1 | 1 | 0 |
| ” | 2½ | 11 | 0 | ” | 1¼ | 1 | 8 |
| ” | 3 | 25 | 0 | ” | 1½ | 2 | 8 |
| Clasp, bastard, wrought . . | 2 | 7 | 0 | ” | 1¾ | 3 | 0 |
| | 2½ | 12 | 0 | ” | 2 | 4 | 0 |
| Clasp, fine, wrought | 1 | 1 | 8 | Brads, fine, billed, cut . . . | ½ | 0 | 3¾ |
| ” | 1¼ | 2 | 0 | | ¾ | 0 | 7¾ |
| ” | 1½ | 3 | 0 | ” | 1 | 1 | 0 |
| ” | 1¾ | 4 | 0 | ” | 1¼ | 1 | 8 |
| ” | 2 | 5 | 0 | ” | 1½ | 2 | 0 |
| ” | 2½ | 7 | 0 | ” | 2 | 3 | 4 |

TABLE 151.—NAILS, IRON OR STEEL: SIZES AND WEIGHTS (*continued*).

| Description. | Length. | Weight per 1,000. | | Description. | Length. | Weight per 1,000. | |
|---|---|---|---|---|---|---|---|
| | In. | Lb. | Oz. | | In. | Lb. | Oz. |
| Brads, flooring, cut | 2¼ | 10 | 0 | Dog, countersunk, wrought | 2 | 21 | 4 |
| " | 2½ | 15 | 0 | | 2½ | 27 | 12 |
| " | 3¼ | 20 | 0 | " | 3 | 39 | 8 |
| Brads, moulder's, fine, cut . . | 3½ | 10 | 8 | Tenter hooks . . | 1½ | 6 | 0 |
| | 4 | 12 | 13 | Mop, caulker's, wrought . . | 4½ | 62 | 0 |
| " | 4½ | 15 | 4 | | 7 | 125 | 0 |
| " | 5 | 17 | 10 | Slating, wrought, galvanised . . | 2 | ... | |
| Tacks, flat head, wrought . . | ⅜ | 0 | 5 | Scupper, wrought . | ¾ | 4 | 0 |
| | ½ | 0 | 8 | " | 1 | 6 | 4 |
| " | ⅝ | 0 | 14 | " | 1¼ | 10 | 4 |
| Tacks, round head, wrought | ⅝ | 1 | 4 | Roofing rivets, wrought with burrs, galvanised, ¼ in. diam. | ½ | ... | |
| Tacks, tinned, flat head, wrought . | ⅜ | 0 | 5½ | | ⅜ | ... | |
| | ½ | 0 | 9 | Glaziers' sprigs . . | ½ | 0 | 4 |
| " | ⅝ | 0 | 15½ | " | ¾ | 0 | 14 |
| Tacks, moulding, wrought . . | 2½ | 19 | 12 | Horse shoe . . | 2 | 5 | 8 |
| | 3 | 32 | 4 | " . . . | 2⅛ | 7 | 0 |
| " | 4 | 54 | 0 | " . . . | 2¼ | 8 | 8 |
| Tacks, flat head, cut . . . | ⅜ | 0 | 5¾ | " . . . | 2⅜ | 10 | 0 |
| | ½ | 0 | 8¼ | " . . . | 2½ | 11 | 0 |
| " | ⅝ | 0 | 12 | " . . . | 2¾ | 13 | 8 |
| Cooper's flat, wrought . . | ¾ | 1 | 8 | Cart wheel tyre . | 3½ | 187 | 8 |
| | 1 | 2 | 4 | " | 4 | 218 | 12 |
| " | 1¼ | 3 | 4 | | | | |

TABLE 152.—GALVANISED WROUGHT IRON CYLINDRICAL CISTERNS.

(Gospel Oak Company.)

| Capacity (about) | Diameter. | Height. | Capacity (about) | Diameter. | Height. |
|---|---|---|---|---|---|
| Gallons. | Inches. | Inches. | Gallons. | Inches. | Inches. |
| 5 | 11 | 17½ | 40 | 21 | 33 |
| 10 | 14 | 21 | 50 | 23 | 35 |
| 15 | 16 | 22 | 60 | 25 | 36 |
| 20 | 18 | 24 | 80 | 27 | 42 |
| 30 | 19½ | 30 | 100 | 28 | 48 |

### Table 153.—Galvanised Wrought Iron Rectangular Cisterns and Tanks.
(Gospel Oak Company.)

**Open Rectangular Cisterns.**

| Capacity (about) | Length. | | Width. | | Depth. | |
|---|---|---|---|---|---|---|
| Gallons. | Ft. | In. | Ft. | In. | Ft. | In. |
| 25 | 2 | 0 | 1 | 5 | 1 | 5 |
| 30 | 2 | 0 | 1 | 6 | 1 | 7 |
| 40 | 2 | 3 | 1 | 8 | 1 | 8 |
| 50 | 2 | 5 | 1 | 10 | 1 | 10 |
| 60 | 2 | 6 | 1 | 11 | 2 | 0 |
| 70 | 2 | 8 | 2 | 2 | 2 | 0 |
| 80 | 2 | 10 | 2 | 3 | 2 | 0 |
| 100 | 3 | 2 | 2 | 3 | 2 | 3 |
| 125 | 3 | 4 | 2 | 7 | 2 | 4 |
| 150 | 3 | 6 | 2 | 7 | 2 | 8 |
| 200 | 3 | 10 | 2 | 11 | 2 | 11 |
| 250 | 4 | 2 | 3 | 3 | 3 | 0 |
| 300 | 4 | 6 | 3 | 7 | 3 | 0 |
| 400 | 5 | 10 | 3 | 9 | 3 | 0 |
| 500 | 6 | 6 | 4 | 1 | 3 | 0 |
| 600 | 7 | 6 | 4 | 1 | 3 | 2 |
| 700 | 8 | 3 | 4 | 1 | 3 | 4 |
| 800 | 8 | 3 | 4 | 5 | 3 | 6 |
| 900 | 8 | 3 | 4 | 11 | 3 | 8 |
| 1000 | 8 | 3 | 4 | 11 | 4 | 0 |

**Closed Hot Water Tanks.**

| Capacity (about) | Length. | | Width. | | Depth. | |
|---|---|---|---|---|---|---|
| Gallons. | Ft. | In. | Ft. | In. | Ft. | In. |
| 20 | 1 | 8 | 1 | 3 | 1 | 6 |
| 25 | 2 | 0 | 1 | 5 | 1 | 5 |
| 30 | 2 | 0 | 1 | 6 | 1 | 7 |
| 40 | 2 | 3 | 1 | 8 | 1 | 8 |
| 50 | 2 | 5 | 1 | 10 | 1 | 10 |
| 60 | 2 | 6 | 1 | 11 | 2 | 0 |
| 80 | 2 | 10 | 2 | 3 | 2 | 0 |
| 100 | 3 | 2 | 2 | 3 | 2 | 3 |

*Note* 1.—The cisterns are constructed of three thicknesses—light; medium, $\frac{1}{8}$ inch bare; $\frac{1}{8}$ inch full.

*Note* 2.—The tanks are constructed of four thicknesses—light, strong, $\frac{1}{8}$ inch bare, $\frac{1}{8}$ inch full.

### Table 154.—Cast-Iron Cylinders:—Weight, by Internal Diameter.
Length, 1 Foot.

| Inside Diam. | Thickness in Inches. $\frac{3}{8}$ | $\frac{1}{2}$ | $\frac{5}{8}$ | $\frac{3}{4}$ | $\frac{7}{8}$ | 1 | $1\frac{1}{8}$ | $1\frac{1}{4}$ |
|---|---|---|---|---|---|---|---|---|
| Ins. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. |
| 1 | 5·06 | 7·36 | 9·97 | 12·9 | 16·1 | 19·6 | ... | ... |
| $1\frac{1}{2}$ | 6·90 | 9·82 | 13·1 | 16·6 | 20·4 | 24·5 | ... | ... |
| 2 | 8·74 | 12·3 | 16·1 | 20·3 | 24·7 | 29·5 | ... | ... |
| $2\frac{1}{2}$ | 10·6 | 14·7 | 19·2 | 23·9 | 29·0 | 34·4 | ... | ... |
| 3 | 12·4 | 17·2 | 22·2 | 27·6 | 33·3 | 39·3 | ... | ... |
| $3\frac{1}{2}$ | 14·3 | 19·6 | 25·3 | 31·3 | 37·6 | 44·2 | ... | ... |
| 4 | 16·1 | 22·1 | 28·4 | 35·0 | 41·9 | 49·1 | ... | ... |
| $4\frac{1}{2}$ | 18·0 | 24·5 | 31·5 | 38·7 | 46·2 | 54·0 | ... | ... |
| 5 | 19·8 | 27·0 | 34·5 | 42·3 | 50·5 | 58.9 | ... | ... |
| $5\frac{1}{2}$ | 21·6 | 29·5 | 37·6 | 46·0 | 54·8 | 63·8 | ... | ... |

TABLE 154.—CAST-IRON CYLINDERS (*continued*).

| Inside Diam. | Thickness in Inches $\frac{3}{8}$ | $\frac{1}{2}$ | $\frac{5}{8}$ | $\frac{3}{4}$ | $\frac{7}{8}$ | 1 | $1\frac{1}{8}$ | $1\frac{1}{4}$ |
|---|---|---|---|---|---|---|---|---|
| Ins. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. |
| 6 | 23·5 | 32·0 | 40·7 | 49·7 | 59·1 | 68·7 | 78·7 | 89·0 |
| $6\frac{1}{2}$ | 25·3 | 34·4 | 43·7 | 53·4 | 63·4 | 73·6 | 84·2 | 95·1 |
| 7 | 27·2 | 36·8 | 46·8 | 57·1 | 67·7 | 78·5 | 89·7 | 101·2 |
| $7\frac{1}{2}$ | 29·0 | 39·3 | 49·9 | 60·8 | 71·9 | 83·5 | 95·3 | 107·4 |
| 8 | 30·8 | 41·7 | 52·9 | 64·4 | 76·2 | 88·4 | 100·8 | 113·5 |
| 9 | 34·5 | 46·6 | 59·0 | 71·8 | 84·8 | 98·2 | 111·8 | 125·8 |
| 10 | 38·2 | 51·5 | 65·1 | 79·2 | 93·4 | 108·0 | 122·9 | 138·1 |
| 11 | 41·9 | 56·5 | 71·2 | 86·5 | 102·0 | 117·8 | 133·9 | 150·3 |
| 12 | 45·6 | 61·4 | 77·5 | 93·9 | 110·6 | 127·6 | 145·0 | 162·6 |
| 13 | 49·2 | 66·3 | 83·6 | 101·2 | 119·2 | 137·5 | 156·0 | 174·9 |
| 14 | 52·9 | 71·2 | 89·7 | 108·6 | 127·8 | 147·3 | 167·1 | 187·2 |
| 15 | 56·6 | 76·1 | 95·9 | 116·0 | 136·4 | 157·1 | 178·1 | 199·4 |
| 16 | 60·3 | 81·0 | 102·0 | 123·3 | 145·0 | 166·9 | 189·1 | 211·7 |
| 17 | 64·0 | 85·9 | 108·2 | 130·7 | 153·6 | 176·7 | 200·2 | 224·0 |
| 18 | 67·7 | 90·8 | 114·3 | 138·1 | 162·2 | 186·5 | 211·2 | 236·2 |

| Inside Diam. | Thickness in Inches. $\frac{3}{8}$ | $\frac{1}{2}$ | $\frac{5}{8}$ | $\frac{3}{4}$ | $\frac{7}{8}$ | 1 | $1\frac{1}{8}$ | $1\frac{1}{4}$ | $1\frac{1}{2}$ | $1\frac{3}{4}$ | 2 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Inch. | Cwts. | Cwts. | Cwts. | Cwts. | Cwts. | Cwts. | Cwts. | Cwts. | Cwts. | Cwts. | Cwts |
| 18 | ·604 | ·811 | 1·02 | 1·23 | 1·45 | 1·67 | 1·89 | 2·11 | 2·56 | 2·86 | 3·29 |
| 19 | ·637 | ·855 | 1·08 | 1·30 | 1·52 | 1·75 | 1·99 | 2·22 | 2·70 | 3·02 | 3·47 |
| 20 | ·670 | ·898 | 1·13 | 1·36 | 1·60 | 1·84 | 2·08 | 2·33 | 2·83 | 3·18 | 3·65 |
| 21 | ·703 | ·942 | 1·19 | 1·43 | 1·68 | 1·93 | 2·18 | 2·44 | 2·96 | 3·34 | 3·84 |
| 22 | ·736 | ·986 | 1·24 | 1·49 | 1·76 | 2·02 | 2·28 | 2·55 | 3·09 | 3·50 | 4·02 |
| 23 | ·769 | 1·03 | 1·29 | 1·56 | 1·83 | 2·10 | 2·38 | 2·66 | 3·22 | 3·66 | 4·20 |
| 24 | ·802 | 1·07 | 1·35 | 1·63 | 1·91 | 2·19 | 2·48 | 2·77 | 3·35 | 3·82 | 4·39 |
| 25 | ·835 | 1·12 | 1·40 | 1·69 | 1·99 | 2·28 | 2·58 | 2·88 | 3·48 | 3·97 | 4·57 |
| 26 | ·868 | 1·16 | 1·46 | 1·76 | 2·06 | 2·37 | 2·68 | 2·99 | 3·62 | 4·13 | 4·75 |
| 27 | ·901 | 1·21 | 1·51 | 1·82 | 2·14 | 2·45 | 2·77 | 3·09 | 3·75 | 4·29 | 4·93 |
| 28 | ·934 | 1·25 | 1·57 | 1·89 | 2·22 | 2·54 | 2·87 | 3·20 | 3·88 | 4·45 | 5·11 |
| 29 | ·967 | 1·29 | 1·62 | 1·96 | 2·29 | 2·63 | 2·97 | 3·31 | 4·01 | 4·62 | 5·30 |
| 30 | ·998 | 1·34 | 1·68 | 2·02 | 2·37 | 2·72 | 3·07 | 3·42 | 4·14 | 4·77 | 5·48 |
| 32 | 1·06 | 1·43 | 1·79 | 2·15 | 2·52 | 2·89 | 3·27 | 3·64 | 4·41 | 5·09 | 5·84 |
| 34 | 1·13 | 1·51 | 1·90 | 2·29 | 2·67 | 3·07 | 3·46 | 3·86 | 4·67 | 5·41 | 6·21 |
| 36 | 1·20 | 1·60 | 2·01 | 2·42 | 2·83 | 3·24 | 3·66 | 4·08 | 4·94 | 5·72 | 6·58 |
| 38 | 1·26 | 1·69 | 2·12 | 2·55 | 2·98 | 3·42 | 3·86 | 4·30 | 5·20 | 6·04 | 6·94 |
| 40 | 1·33 | 1·77 | 2·23 | 2·68 | 3·14 | 3·59 | 4·05 | 4·52 | 5·47 | 6·36 | 7·31 |
| 42 | 1·39 | 1·86 | 2·34 | 2·81 | 3·29 | 3·77 | 4·25 | 4·74 | 5·73 | 6·68 | 7·6[illegible] |
| 45 | 1·49 | 1·99 | 2·50 | 3·01 | 3·52 | 4·03 | 4·55 | 5·07 | 6·13 | 7·15 | 8·2[illegible] |
| 48 | 1·59 | 2·12 | 2·66 | 3·21 | 3·75 | 4·30 | 4·85 | 5·40 | 6·52 | 7·63 | 8·7[illegible] |

TABLE 154.—CAST IRON CYLINDERS (*continued*).

| Inside Diam. | Thickness in Inches. | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | $\frac{5}{8}$ | $\frac{3}{4}$ | $\frac{7}{8}$ | 1 | $1\frac{1}{8}$ | $1\frac{1}{4}$ | $1\frac{3}{8}$ | $1\frac{1}{2}$ | $1\frac{3}{4}$ | 2 | $2\frac{1}{4}$ |
| Inch. | Cwts. | Cwts. | Cwts. | Cwts. | Cwts. | Cwts. | Cwts. | Cwts. | Cwts. | Cwts. | Cwts. |
| 48 | 2·66 | 3·21 | 3·75 | 4·30 | 4·85 | 5·40 | 5·96 | 6·52 | 7·63 | 8·77 | 9·91 |
| 51 | 2·82 | 3·40 | 3·98 | 4·56 | 5·14 | 5·73 | 6·32 | 6·91 | 8·09 | 9·29 | 10·5 |
| 54 | 2·99 | 3·60 | 4·21 | 4·82 | 5·44 | 6·06 | 6·69 | 7·31 | 8·55 | 9·82 | 11·1 |
| 57 | 3·15 | 3·80 | 4·44 | 5·09 | 5·73 | 6·38 | 7·05 | 7·70 | 9·01 | 10·4 | 11·7 |
| 60 | 3·32 | 4·00 | 4·67 | 5·35 | 6·03 | 6·71 | 7·41 | 8·10 | 9·47 | 10·9 | 12·3 |
| 63 | 3·48 | 4·19 | 4·90 | 5·61 | 6·33 | 7·04 | 7·78 | 8·49 | 9·93 | 11·4 | 12·9 |
| 66 | 3·64 | 4·39 | 5·13 | 5·88 | 6·62 | 7·37 | 8·14 | 8·89 | 10·4 | 11·9 | 13·5 |
| 69 | 3·81 | 4·59 | 5·36 | 6·14 | 6·92 | 7·70 | 8·51 | 9·28 | 10·9 | 12·5 | 14·1 |
| 72 | 3·97 | 4·78 | 5·59 | 6·40 | 7·21 | 8·03 | 8·87 | 9·67 | 11·3 | 13·0 | 14·7 |
| 75 | 4·14 | 4·98 | 5·82 | 6·66 | 7·51 | 8·36 | 9·24 | 10·1 | 11·8 | 13·5 | 15·2 |
| 78 | 4·30 | 5·18 | 6·05 | 6·93 | 7·81 | 8·69 | 9·60 | 10·5 | 12·2 | 14·0 | 15·8 |
| 81 | 4·46 | 5·38 | 6·28 | 7·19 | 8·10 | 9·02 | 9·97 | 10·9 | 12·7 | 14·6 | 16·4 |
| 84 | 4·63 | 5·57 | 6·51 | 7·45 | 8·40 | 9·35 | 10·3 | 11·3 | 13·2 | 15·1 | 17·0 |
| 87 | 4·79 | 5·77 | 6·74 | 7·72 | 8·69 | 9·67 | 10·7 | 11·6 | 13·6 | 15·6 | 17·6 |
| 90 | 4·96 | 5·97 | 6·97 | 7·98 | 8·99 | 10·0 | 11·1 | 12·0 | 14·1 | 16·1 | 18·2 |
| 93 | 5·12 | 6·17 | 7·20 | 8·24 | 9·29 | 10·3 | 11·4 | 12·4 | 14·5 | 16·7 | 18·8 |
| 96 | 5·28 | 6·36 | 7·43 | 8·51 | 9·58 | 10·7 | 11·8 | 12·8 | 15·0 | 17·2 | 19·4 |
| 99 | 5·45 | 6·56 | 7·66 | 8·77 | 9·88 | 11·0 | 12·2 | 13·2 | 15·5 | 17·7 | 20·0 |
| 102 | 5·61 | 6·76 | 7·89 | 9·03 | 10·2 | 11·3 | 12·5 | 13·6 | 15·9 | 18·2 | 20·6 |
| 105 | 5·78 | 6·95 | 8·12 | 9·29 | 10·5 | 11·7 | 12·9 | 14·0 | 16·4 | 18·8 | 21·2 |
| 108 | 5·94 | 7·15 | 8·36 | 9·56 | 10·8 | 12·0 | 13·3 | 14·4 | 16·8 | 19·3 | 21·8 |
| 111 | 6·10 | 7·35 | 8·59 | 9·82 | 11·1 | 12·3 | 13·6 | 14·8 | 17·3 | 19·8 | 22·3 |
| 114 | 6·27 | 7·55 | 8·82 | 10·1 | 11·4 | 12·6 | 14·0 | 15·2 | 17·8 | 20·3 | 22·9 |
| 117 | 6·43 | 7·74 | 9·05 | 10·4 | 11·7 | 13·0 | 14·3 | 15·6 | 18·2 | 20·9 | 23·5 |
| 120 | 6·59 | 7·94 | 9·28 | 10·6 | 12·0 | 13·3 | 14·7 | 16·0 | 18·7 | 21·4 | 24·1 |

TABLE 156.—CAST-IRON CYLINDERS: WEIGHT BY EXTERNAL DIAMETER.

Length, 1 Foot.

| External Diameter. | Thickness in Inches. | | | | | | |
|---|---|---|---|---|---|---|---|
| | $\frac{3}{8}$ | $\frac{7}{16}$ | $\frac{1}{2}$ | $\frac{5}{8}$ | $\frac{3}{4}$ | $\frac{7}{8}$ | 1 |
| Inches. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. |
| 3 | 9·65 | 11·0 | 12·3 | 14·6 | 16·6 | 18·3 | 19·6 |
| $3\frac{1}{2}$ | 11·5 | 13·2 | 14·7 | 17·6 | 20·3 | 22·6 | 24·5 |
| 4 | 13·3 | 15·3 | 17·2 | 20·7 | 24·0 | 26·9 | 29·5 |
| $4\frac{1}{2}$ | 15·2 | 17·5 | 19·6 | 23·8 | 27·7 | 31·1 | 34·4 |
| 5 | 17·0 | 19·6 | 22·1 | 26·9 | 31·5 | 35·4 | 39·3 |
| $5\frac{1}{2}$ | 18·9 | 21·8 | 24·5 | 29·9 | 35·2 | 39·7 | 44·2 |
| 6 | 20·7 | 23·9 | 27·0 | 33·0 | 38·9 | 44·0 | 49·1 |
| $6\frac{1}{2}$ | 22·5 | 26·0 | 29·5 | 36·1 | 42·6 | 48·3 | 54·0 |

TABLE 156.—CAST-IRON CYLINDERS (*continued*).

| External Diameter. | Thickness in Inches. | | | | | | |
|---|---|---|---|---|---|---|---|
| | $\frac{3}{8}$ | $\frac{7}{16}$ | $\frac{1}{2}$ | $\frac{5}{8}$ | $\frac{3}{4}$ | $\frac{7}{8}$ | 1 |
| Inches. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. |
| 7 | 24·4 | 28·2 | 31·9 | 39·1 | 46·4 | 52·6 | 58·9 |
| 7½ | 26·2 | 30·3 | 34·4 | 42·2 | 50·1 | 56·9 | 63·8 |
| 8 | 28·1 | 32·5 | 36·8 | 45·3 | 53·8 | 61·2 | 68·7 |
| 8½ | 29·9 | 34·6 | 39·3 | 48·3 | 57·5 | 65·5 | 73·6 |
| 9 | 31·8 | 36·8 | 41·7 | 51·4 | 61·3 | 69·8 | 78·5 |
| 9½ | 33·6 | 38·9 | 44·2 | 54·5 | 65·0 | 74·1 | 83·5 |
| 10 | 35·4 | 41·1 | 46·6 | 57·5 | 68·7 | 78·4 | 88·4 |
| 11 | 39·1 | 45·4 | 51·5 | 63·7 | 76·0 | 87·0 | 98·2 |
| 12 | 42·8 | 49·7 | 56·5 | 69·8 | 83·4 | 95·6 | 108·0 |
| 13 | 46·5 | 54·0 | 61·4 | 75·9 | 90·7 | 104·2 | 117·8 |
| 14 | 50·2 | 58·3 | 66·3 | 82·1 | 98·0 | 112·8 | 127·6 |
| 15 | 53·8 | 62·6 | 71·2 | 88·2 | 105·4 | 121·3 | 137·4 |
| 16 | 57·5 | 66·9 | 76·1 | 94·3 | 112·7 | 129·9 | 147·3 |
| 17 | 61·2 | 71·1 | 81·0 | 100·5 | 120·0 | 138·5 | 157·1 |
| 18 | 64·9 | 75·4 | 85·9 | 106·6 | 127·4 | 147·1 | 166·9 |
| 19 | 68·6 | 79·7 | 90·8 | 112·8 | 134·7 | 155·7 | 176·7 |
| 20 | 72·3 | 84·0 | 95·7 | 118·9 | 142·0 | 164·3 | 186·5 |
| 21 | 75·9 | 88·3 | 100·6 | 125·0 | 149·4 | 172·9 | 196·4 |
| 22 | 79·6 | 92·6 | 105·5 | 131·2 | 156·7 | 181·5 | 206·2 |
| 23 | 83·3 | 96·9 | 110·5 | 137·3 | 164·0 | 190·1 | 215·0 |
| 24 | 87·0 | 101·2 | 115·4 | 143·4 | 171·4 | 198·7 | 225·8 |
| 25 | 90·7 | 105·5 | 120·3 | 149·6 | 178·7 | 207·2 | 235·6 |
| 26 | 94·3 | 109·8 | 125·2 | 155·7 | 186·1 | 215·8 | 245·4 |
| 27 | 98·0 | 114·1 | 130·1 | 161·8 | 193·4 | 224·4 | 255·3 |
| 28 | 101·7 | 118·4 | 135·0 | 168·0 | 200·7 | 233·0 | 265·1 |
| 29 | 105·4 | 122·7 | 139·9 | 174·1 | 208·1 | 241·6 | 274·9 |
| 30 | 109·1 | 127·0 | 144·8 | 180·2 | 215·4 | 250·2 | 284·7 |
| 31 | 112·8 | 131·3 | 149·7 | 186·4 | 222·7 | 258·8 | 294·5 |
| 32 | 116·4 | 135·6 | 154·6 | 192·5 | 230·1 | 267·4 | 304·3 |
| 33 | 120·1 | 139·9 | 159·5 | 198·7 | 237·5 | 276·0 | 314·2 |
| 34 | 123·8 | 144·2 | 164·5 | 204·8 | 244·8 | 284·6 | 324·0 |
| 35 | 127·5 | 148·5 | 169·4 | 210·9 | 252·2 | 293·1 | 333·8 |
| 36 | 131·2 | 152·7 | 174·3 | 217·1 | 259·5 | 301·7 | 343·6 |
| 38 | 138·5 | 161·3 | 184·1 | 229·3 | 274·3 | 318·9 | 363·2 |
| 40 | 145·9 | 169·9 | 193·9 | 241·6 | 289·0 | 336·1 | 382·9 |
| 42 | 153·3 | 178·5 | 203·7 | 253·9 | 303·7 | 353·3 | 402·5 |
| 45 | 164·3 | 191·2 | 218·5 | 272·3 | 325·8 | 379·1 | 432·0 |
| 48 | 175·4 | 203·8 | 233·2 | 290·7 | 347·9 | 404·8 | 461·4 |
| 51 | 186·4 | 216·5 | 247·9 | 309·1 | 370·0 | 430·6 | 490·9 |
| 54 | 197·5 | 229·2 | 262·6 | 327·5 | 392·1 | 456·4 | 520·3 |
| 57 | 208·5 | 241·8 | 277·4 | 345·9 | 414·2 | 482·1 | 549·8 |
| 60 | 219·6 | 254·5 | 292·1 | 364·3 | 436·3 | 507·9 | 579·3 |

TABLE 156.—CAST-IRON CYLINDERS (*continued*).

| External Diameter. | Thickness in Inches. | | | | | | |
|---|---|---|---|---|---|---|---|
| | $\frac{3}{8}$ | $\frac{7}{16}$ | $\frac{1}{2}$ | $\frac{5}{8}$ | $\frac{3}{4}$ | $\frac{7}{8}$ | 1 |
| Inches. | Cwts. | Cwts. | Cwts. | Cwts. | Cwts. | Cwts. | Cwts. |
| 63 | 2·06 | 2·39 | 2·74 | 3·42 | 4·09 | 4·77 | 5·43 |
| 66 | 2·16 | 2·50 | 2·87 | 3·58 | 4·29 | 5·00 | 5·70 |
| 69 | 2·26 | 2·62 | 3·00 | 3·75 | 4·49 | 5·23 | 5·96 |
| 72 | 2·36 | 2·74 | 3·14 | 3·91 | 4·69 | 5·46 | 6·22 |
| 75 | 2·45 | 2·85 | 3·27 | 4·08 | 4·88 | 5·69 | 6·49 |
| 78 | 2·55 | 2·97 | 3·40 | 4·24 | 5·08 | 5·92 | 6·75 |
| 81 | 2·65 | 3·09 | 3·53 | 4·41 | 5·28 | 6·15 | 7·01 |
| 84 | 2·75 | 3·20 | 3·66 | 4·57 | 5·47 | 6·38 | 7·28 |
| 90 | 2·95 | 3·43 | 3·92 | 4·90 | 5·87 | 6·84 | 7·80 |
| 96 | 3·15 | 3·67 | 4·19 | 5·23 | 6·26 | 7·30 | 8·33 |

| External Diameter. | Thickness in Inches. | | | | | | |
|---|---|---|---|---|---|---|---|
| | $1\frac{1}{8}$ | $1\frac{1}{4}$ | $1\frac{3}{8}$ | $1\frac{1}{2}$ | $1\frac{3}{4}$ | 2 | $2\frac{1}{4}$ |
| Inches. | Cwts. | Cwts. | Cwts. | Cwts. | Cwts. | Cwts. | Cwts. |
| 6 | ·481 | ·520 | ·557 | ·592 | ·652 | ·701 | ·740 |
| $6\frac{1}{2}$ | ·530 | ·575 | ·618 | ·657 | ·729 | ·789 | ·838 |
| 7 | ·579 | ·630 | ·678 | ·723 | ·805 | ·876 | ·938 |
| $7\frac{1}{2}$ | ·629 | ·685 | ·738 | ·789 | ·882 | ·964 | 1·04 |
| 8 | ·678 | ·740 | ·799 | ·855 | ·959 | 1·05 | 1·14 |
| $8\frac{1}{2}$ | ·727 | ·794 | ·859 | ·921 | 1·04 | 1·14 | 1·23 |
| 9 | ·777 | ·849 | ·919 | ·986 | 1·11 | 1·23 | 1·33 |
| $9\frac{1}{2}$ | ·826 | ·904 | ·980 | 1·05 | 1·19 | 1·31 | 1·43 |
| 10 | ·875 | ·959 | 1·04 | 1·12 | 1·27 | 1·40 | 1·53 |
| 11 | ·974 | 1·07 | 1·16 | 1·25 | 1·42 | 1·58 | 1·73 |
| 12 | 1·07 | 1·18 | 1·28 | 1·38 | 1·57 | 1·75 | 1·92 |
| 13 | 1·17 | 1·29 | 1·40 | 1·51 | 1·73 | 1·93 | 2·12 |
| 14 | 1·27 | 1·40 | 1·52 | 1·64 | 1·88 | 2·10 | 2·32 |
| 15 | 1·37 | 1·51 | 1·65 | 1·78 | 2·03 | 2·28 | 2·52 |
| 16 | 1·47 | 1·62 | 1·77 | 1·91 | 2·19 | 2·45 | 2·71 |
| 17 | 1·57 | 1·73 | 1·89 | 2·04 | 2·34 | 2·63 | 2·91 |
| 18 | 1·66 | 1·84 | 2·01 | 2·17 | 2·49 | 2·81 | 3·11 |
| 20 | 1·86 | 2·06 | 2·25 | 2·43 | 2·80 | 3·16 | 3·50 |
| 22 | 2·06 | 2·27 | 2·49 | 2·70 | 3·11 | 3·51 | 3·90 |
| 24 | 2·26 | 2·49 | 2·73 | 2·96 | 3·41 | 3·86 | 4·29 |
| 27 | 2·55 | 2·82 | 3·09 | 3·35 | 3·87 | 4·38 | 4·88 |
| 30 | 2·85 | 3·15 | 3·46 | 3·75 | 4·33 | 4·91 | 5·47 |
| 33 | 3·14 | 3·48 | 3·82 | 4·14 | 4·79 | 5·44 | 6·06 |
| 36 | 3·44 | 3·81 | 4·18 | 4·54 | 5·25 | 5·96 | 6·66 |
| 39 | 3·74 | 4·14 | 4·54 | 4·93 | 5·72 | 6·49 | 7·25 |

TABLE 156.—CAST-IRON CYLINDERS (*continued*).

| External Diameter. | Thickness in Inches. | | | | | | |
|---|---|---|---|---|---|---|---|
| | $1\frac{1}{8}$ | $1\frac{1}{4}$ | $1\frac{3}{8}$ | $1\frac{1}{2}$ | $1\frac{3}{4}$ | 2 | $2\frac{1}{4}$ |
| Inches. | Cwts. | Cwts. | Cwts. | Cwts. | Cwts. | Cwts. | Cwts. |
| 42 | 4·03 | 4·47 | 4·90 | 5·33 | 6·18 | 7·01 | 7·84 |
| 45 | 4·33 | 4·79 | 5·26 | 5·72 | 6·64 | 7·54 | 8·43 |
| 48 | 4·62 | 5·12 | 5·62 | 6·12 | 7·10 | 8·07 | 9·02 |
| 51 | 4·92 | 5·45 | 5·98 | 6·51 | 7·56 | 8·59 | 9·61 |
| 54 | 5·22 | 5·78 | 6·35 | 6·91 | 8·02 | 9·12 | 10·2 |
| 57 | 5·51 | 6·11 | 6·71 | 7·30 | 8·48 | 9·64 | 10·8 |
| 60 | 5·81 | 6·44 | 7·07 | 7·70 | 8·94 | 10·2 | 11·4 |
| Ft. In. | | | | | | | |
| 5 3 | 6·10 | 6·77 | 7·43 | 8·09 | 9·40 | 10·7 | 12·0 |
| 5 6 | 6·40 | 7·09 | 7·79 | 8·48 | 9·86 | 11·2 | 12·6 |
| 5 9 | 6·70 | 7·42 | 8·15 | 8·88 | 10·3 | 11·8 | 13·2 |
| 6 0 | 7·00 | 7·75 | 8·51 | 9·27 | 10·8 | 12·3 | 13·8 |
| 6 3 | 7·29 | 8·08 | 8·88 | 9·67 | 11·2 | 12·8 | 14·4 |
| 6 6 | 7·58 | 8·41 | 9·24 | 10·1 | 11·7 | 13·3 | 14·9 |
| 6 9 | 7·88 | 8·74 | 9·60 | 10·5 | 12·2 | 13·9 | 15·5 |
| 7 0 | 8·17 | 9·07 | 9·96 | 10·9 | 12·6 | 14·4 | 16·1 |
| 7 6 | 8·77 | 9·72 | 10·7 | 11·6 | 13·5 | 15·4 | 17·3 |
| 8 0 | 9·36 | 10·4 | 11·4 | 12·4 | 14·5 | 16·5 | 18·5 |
| 8 6 | 9·95 | 11·0 | 12·1 | 13·2 | 15·4 | 17·5 | 19·7 |
| 9 0 | 10·5 | 11·7 | 12·9 | 14·0 | 16·3 | 18·6 | 20·8 |
| 9 6 | 11·1 | 12·3 | 13·6 | 14·8 | 17·2 | 19·6 | 22·0 |
| 10 0 | 11·7 | 13·0 | 14·3 | 15·6 | 18·1 | 20·7 | 23·2 |
| 10 6 | 12·3 | 13·7 | 15·0 | 16·4 | 19·1 | 21·7 | 24·4 |
| 11 0 | 12·9 | 14·3 | 15·7 | 17·2 | 20·0 | 22·8 | 25·6 |
| 11 6 | 13·5 | 15·0 | 16·5 | 17·9 | 20·9 | 23·8 | 26·7 |
| 12 0 | 14·1 | 15·6 | 17·2 | 18·7 | 21·8 | 24·9 | 27·9 |
| 13 0 | 15·3 | 16·9 | 18·6 | 20·3 | 23·7 | 27·0 | 30·3 |
| 14 0 | 16·5 | 18·3 | 20·1 | 21·9 | 25·5 | 29·1 | 32·7 |
| 15 0 | 17·7 | 19·6 | 21·5 | 23·5 | 27·3 | 31·2 | 35·0 |
| 16 0 | 18·8 | 20·9 | 23·0 | 25·0 | 29·2 | 33·3 | 37·4 |
| 17 0 | 20·0 | 22·2 | 24·4 | 26·6 | 31·0 | 35·4 | 39·8 |
| 18 0 | 21·2 | 23·5 | 25·9 | 28·2 | 32·9 | 37·5 | 42·2 |
| 19 0 | 22·4 | 24·8 | 27·3 | 29·8 | 34·7 | 39·6 | 44·5 |
| 20 0 | 23·6 | 26·1 | 28·8 | 31·4 | 36·5 | 41·7 | 46·9 |

ABLE 157.—CAST-IRON BALLS AND THEIR CIRCUMSCRIBING CYLINDERS: WEIGHTS.

| Diameter. | Weight of Ball. | Weight of Circumscribing Cylinder. | Diameter. | Weight of Ball. | Weight of Circumscribing Cylinder. |
|---|---|---|---|---|---|
| Inches. | Pounds. | Pounds. | Inches. | Cwts. | Cwts. |
| 2 | 1·09 | 1·64 | 10 | 1·22 | 1·83 |
| 2½ | 2·13 | 3·19 | 11 | 1·62 | 2·43 |
| 3 | 3·68 | 5·52 | 12 | 2·10 | 3·15 |
| 3½ | 5·85 | 8·77 | 14 | 3·34 | 5·01 |
| 4 | 8·73 | 13·1 | 16 | 4·99 | 7·48 |
| 4½ | 12·4 | 18·6 | 18 | 7·10 | 10·65 |
| 5 | 17·0 | 25·5 | 20 | 9·74 | 14·61 |
| 5½ | 22·7 | 34·0 | 22 | 12·97 | 19·45 |
| 6 | 29·5 | 44·2 | 24 | 16·83 | 25·25 |
| 6½ | 37·5 | 56·2 | 26 | 21·40 | 32·10 |
| 7 | 46·8 | 70·2 | 28 | 26·72 | 40·08 |
| 7½ | 57·5 | 86·2 | 30 | 32·87 | 49·31 |
| 8 | 69·8 | 104·7 | Cylinder, one-half heavier than ball. | | |
| 9 | 99·4 | 149·1 | | | |

ABLE 158.—COPPER AND BRASS: WEIGHT OF ONE LINEAL FOOT OF ROUND BOLTS OR RODS.

(Elliott's Metal Company.)

On the basis of 558lb. per cubic foot of Copper; and 534lb. for Brass.

| Diameter. | Copper. | Brass. | Diameter. | Copper. | Brass. |
|---|---|---|---|---|---|
| Inches. | Pounds. | Pounds. | Inches. | Pounds. | Pounds. |
| ½ | ·76 | ·72 | 2¼ | 15·40 | 14·74 |
| 9/16 | ·96 | ·92 | 2⅜ | 17·16 | 16·42 |
| ⅝ | 1·19 | 1·13 | 2½ | 19·01 | 18·19 |
| 11/16 | 1·43 | 1·37 | 2⅝ | 29·96 | 20·06 |
| ¾ | 1·71 | 1·63 | 2¾ | 23·01 | 22·01 |
| 13/16 | 2·01 | 1·92 | 2⅞ | 25·15 | 24·06 |
| ⅞ | 2·33 | 2·23 | 3 | 27·38 | 26·20 |
| 15/16 | 2·67 | 2·56 | 3¼ | 32·14 | 30·75 |
| 1 | 3·04 | 2·91 | 3½ | 37·27 | 35·67 |
| 1 1/16 | 3·43 | 3·28 | 3¾ | 42·78 | 40·93 |
| 1⅛ | 3·85 | 3·68 | 4 | 48·67 | 46·57 |
| 1 3/16 | 4·29 | 4·10 | 4¼ | 54·94 | 52·58 |
| 1¼ | 4·75 | 4·55 | 4½ | 61·61 | 58·95 |
| 1⅜ | 5·75 | 5·50 | 4¾ | 68·66 | 65·70 |
| 1½ | 6·84 | 6·55 | 5 | 76·06 | 72·79 |
| 1⅝ | 8·03 | 7·68 | 5¼ | 83·86 | 80·24 |
| 1¾ | 9·32 | 8·91 | 5½ | 92·03 | 88·06 |
| 1⅞ | 10·69 | 10·23 | 6 | 109·55 | 104·82 |
| 2 | 12·17 | 11·64 | 6½ | 128·57 | 123·03 |
| 2⅛ | 13·73 | 13·14 | 7 | 149·10 | 142·68 |

TABLE 159.—COPPER AND BRASS: WEIGHT OF ONE SQUARE FOOT.
(Elliott's Metal Company.)
On the basis of 558 lb. per cubic foot of Copper, and 534 lb. for Brass.

| Thickness. | Weight per Square Foot. | | Thickness. | Weight per Square Foot. | |
|---|---|---|---|---|---|
| | Copper. | Brass. | | Copper. | Brass. |
| I. W. G. | Pounds. | Pounds. | I. W. G. | Pounds. | Pounds. |
| 1 | 13·950 | 13·350 | 22 | 1·302 | 1·246 |
| 2 | 12·834 | 12·282 | 23 | 1·116 | 1·068 |
| 3 | 11·718 | 11·214 | 24 | 1·023 | ·979 |
| 4 | 10·788 | 10·324 | 25 | ·930 | ·890 |
| 5 | 9·858 | 9·434 | 26 | ·837 | ·801 |
| 6 | 8·928 | 8·544 | 27 | ·762 | ·729 |
| 7 | 8·184 | 7·832 | 28 | ·688 | ·658 |
| 8 | 7·440 | 7·120 | 29 | ·632 | ·605 |
| 9 | 6·696 | 6·408 | 30 | ·576 | ·551 |
| 10 | 5·952 | 5·696 | 31 | ·539 | ·516 |
| 11 | 5·394 | 5·162 | 32 | ·502 | ·480 |
| 12 | 4·836 | 4·628 | 33 | ·465 | ·445 |
| 13 | 4·278 | 4·094 | 34 | ·427 | ·409 |
| 14 | 3·720 | 3·560 | 35 | ·390 | ·373 |
| 15 | 3·348 | 3·204 | 36 | ·353 | ·338 |
| 16 | 2·976 | 2·848 | 37 | ·316 | ·302 |
| 17 | 2·604 | 2·492 | 38 | ·279 | ·267 |
| 18 | 2·232 | 2·136 | 39 | ·241 | ·231 |
| 19 | 1·860 | 1·780 | 40 | ·223 | ·213 |
| 20 | 1·624 | 1·602 | 41 | ·204 | ·195 |
| 21 | 1·488 | 1·424 | 42 | ·186 | ·178 |

TABLE 160.—COPPER: APPROXIMATE WEIGHT OF ONE SQUARE FOOT.
(Elliott's Metal Company.)

| Thickness, I. W. G. | Approximate Weight per Square Foot. | Thickness, I. W. G. | Approximate Weight per Square Foot. | Thickness, I. W. G. | Approximate Weight per Square Foot. |
|---|---|---|---|---|---|
| No. | Lbs. Oz. | No. | Lbs. Oz. | No. | Lbs. Oz. |
| 1 | 14 0 | 11 | 5 6 | 21 | 1 7½ |
| 2 | 12 14 | 12 | 4 13 | 22 | 1 5 |
| 3 | 11 12 | 13 | 4 4 | 23 | 1 2½ |
| 4 | 10 12 | 14 | 3 12 | 24 | 1 0 |
| 5 | 9 14 | 15 | 3 6 | 25 | 0 14¾ |
| 6 | 9 0 | 16 | 3 0 | 26 | 0 13½ |
| 7 | 8 2 | 17 | 2 10 | 27 | 0 12¼ |
| 8 | 7 6 | 18 | 2 4 | 28 | 0 11 |
| 9 | 6 11 | 19 | 1 14 | 29 | 0 10 |
| 10 | 6 0 | 20 | 1 10 | 30 | 0 9[illegible] |

## TABLE 161.—WEIGHT OF SEAMLESS COPPER TUBES: IMPERIAL

Calculated on the basis of

| 1884. | | THICKNESS | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| I. W. G. | | 0000 | 000 | 00 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Inches. | | 0·400 | 0·372 | 0·348 | 0·324 | 0·300 | 0·276 | 0·252 | 0·232 | 0·212 | 0·192 | 0·176 |
| | | $\frac{13}{32}$ *b* | $\frac{3}{8}$ *b* | $\frac{11}{32}$ *f* | $\frac{21}{64}$ *b* | $\frac{19}{64}$ *f* | $\frac{9}{32}$ *b* | $\frac{1}{4}$ *f* | $\frac{15}{64}$ *b* | $\frac{7}{32}$ *b* | $\frac{3}{16}$ *f* | $\frac{11}{64}$ *f* |
| Millimetres. | | 10·160 | 9·449 | 8·839 | 8·229 | 7·620 | 7·010 | 6·401 | 5·893 | 5·385 | 4·877 | 4·470 |
| Internal Diameter. | | WEIGHT OF A LINEAL | | | | | | | | | | |
| Inches. | Millim. | | | | | | | | | | | |
| $\frac{1}{8}$ | 3·2 | 2·54 | 2·24 | 1·99 | 1·76 | 1·54 | 1·34 | 1·15 | 1·00 | 0·86 | 0·74 | 0·64 |
| $\frac{1}{4}$ | 6·3 | 3·14 | 2·80 | 2·52 | 2·25 | 2·00 | 1·76 | 1·53 | 1·35 | 1·18 | 1·03 | 0·91 |
| $\frac{3}{8}$ | 9·5 | 3·75 | 3·36 | 3·04 | 2·74 | 2·45 | 2·17 | 1·91 | 1·70 | 1·50 | 1·32 | 1·17 |
| $\frac{1}{2}$ | 12·7 | 4·35 | 3·92 | 3·57 | 3·23 | 2·90 | 2·59 | 2·29 | 2·05 | 1·83 | 1·61 | 1·44 |
| $\frac{5}{8}$ | 15·9 | 4·96 | 4·49 | 4·10 | 3·72 | 3·36 | 3·01 | 2·67 | 2·40 | 2·15 | 1·90 | 1·70 |
| $\frac{3}{4}$ | 19·0 | 5·56 | 5·05 | 4·62 | 4·21 | 3·81 | 3·43 | 3·05 | 2·76 | 2·47 | 2·19 | 1·97 |
| $\frac{7}{8}$ | 22·2 | 6·17 | 5·61 | 5·15 | 4·70 | 4·26 | 3·84 | 3·44 | 3·11 | 2·79 | 2·48 | 2·24 |
| 1 | 25·4 | 6·77 | 6·17 | 5·67 | 5·19 | 4·72 | 4·26 | 3·82 | 3·46 | 3·11 | 2·77 | 2·50 |
| $1\frac{1}{8}$ | 28·6 | 7·38 | 6·74 | 6·20 | 5·68 | 5·17 | 4·68 | 4·20 | 3·81 | 3·43 | 3·06 | 2·77 |
| $1\frac{1}{4}$ | 31·7 | 7·98 | 7·30 | 6·73 | 6·17 | 5·62 | 5·09 | 4·58 | 4·16 | 3·75 | 3·35 | 3·04 |
| $1\frac{3}{8}$ | 34·9 | 8·59 | 7·86 | 7·25 | 6·66 | 6·08 | 5·51 | 4·96 | 4·51 | 4·07 | 3·64 | 3·30 |
| $1\frac{1}{2}$ | 38·1 | 9·19 | 8·42 | 7·78 | 7·15 | 6·53 | 5·93 | 5·34 | 4·86 | 4·39 | 3·93 | 3·57 |
| $1\frac{5}{8}$ | 41·3 | 9·80 | 8·99 | 8·31 | 7·64 | 6·99 | 6·35 | 5·72 | 5·21 | 4·71 | 4·22 | 3·83 |
| $1\frac{3}{4}$ | 44·4 | 10·40 | 9·55 | 8·83 | 8·13 | 7·44 | 6·76 | 6·10 | 5·56 | 5·03 | 4·51 | 4·10 |
| $1\frac{7}{8}$ | 47·6 | 11·01 | 10·11 | 9·36 | 8·62 | 7·89 | 7·18 | 6·48 | 5·91 | 5·35 | 4·80 | 4·37 |
| 2 | 50·8 | 11·61 | 10·67 | 9·88 | 9·11 | 8·35 | 7·60 | 6·86 | 6·26 | 5·67 | 5·09 | 4·63 |
| $2\frac{1}{8}$ | 54·0 | 12·22 | 11·24 | 10·41 | 9·60 | 8·80 | 8·02 | 7·25 | 6·61 | 5·99 | 5·38 | 4·90 |
| $2\frac{1}{4}$ | 57·1 | 12·82 | 11·80 | 10·94 | 10·09 | 9·25 | 8·43 | 7·63 | 6·97 | 6·31 | 5·67 | 5·16 |
| $2\frac{3}{8}$ | 60·3 | 13·43 | 12·36 | 11·46 | 10·58 | 9·71 | 8·85 | 8·01 | 7·32 | 6·63 | 5·96 | 5·43 |
| $2\frac{1}{2}$ | 63·5 | 14·03 | 12·92 | 11·99 | 11·07 | 10·16 | 9·27 | 8·39 | 7·67 | 6·95 | 6·25 | 5·70 |
| $2\frac{5}{8}$ | 66·7 | 14·64 | 13·49 | 12·52 | 11·56 | 10·62 | 9·69 | 8·77 | 8·02 | 7·28 | 6·54 | 5·96 |
| $2\frac{3}{4}$ | 69·8 | 15·24 | 14·05 | 13·04 | 12·05 | 11·07 | 10·10 | 9·15 | 8·37 | 7·60 | 6·83 | 6·23 |
| $2\frac{7}{8}$ | 73·0 | 15·85 | 14·61 | 13·57 | 12·54 | 11·52 | 10·52 | 9·53 | 8·72 | 7·92 | 7·12 | 6·50 |
| 3 | 76·2 | 16·45 | 15·17 | 14·09 | 13·03 | 11·98 | 10·94 | 9·91 | 9·07 | 8·24 | 7·41 | 6·76 |
| $3\frac{1}{4}$ | 82·5 | 17·66 | 16·30 | 15·15 | 14·01 | 12·88 | 11·77 | 10·68 | 9·77 | 8·88 | 7·99 | 7·29 |
| $3\frac{1}{2}$ | 88·9 | 18·87 | 17·42 | 16·20 | 14·99 | 13·79 | 12·61 | 11·44 | 10·47 | 9·52 | 8·58 | 7·83 |
| $3\frac{3}{4}$ | 95·2 | 20·08 | 18·55 | 17·25 | 15·97 | 14·70 | 13·44 | 12·20 | 11·18 | 10·16 | 9·16 | 8·36 |
| 4 | 101·6 | 21·20 | 19·67 | 18·30 | 16·95 | 15·62 | 14·28 | 12·96 | 11·88 | 10·80 | 9·74 | 8·89 |
| $4\frac{1}{4}$ | 107·9 | 22·50 | 20·80 | 19·36 | 17·93 | 16·51 | 15·11 | 13·72 | 12·58 | 11·44 | 10·32 | 9·42 |
| $4\frac{1}{2}$ | 114·3 | 23·71 | 21·93 | 20·41 | 18·91 | 17·42 | 15·95 | 14·49 | 13·28 | 12·08 | 10·90 | 9·96 |
| $4\frac{3}{4}$ | 120·6 | 24·92 | 23·05 | 21·46 | 19·89 | 18·33 | 16·78 | 15·25 | 13·98 | 12·73 | 11·48 | 10·49 |
| 5 | 127·0 | 26·13 | 24·18 | 22·51 | 20·87 | 19·23 | 17·62 | 16·01 | 14·68 | 13·37 | 12·06 | 11·02 |
| $5\frac{1}{4}$ | 133·3 | 27·34 | 25·30 | 23·57 | 21·85 | 20·14 | 18·45 | 16·77 | 15·39 | 14·01 | 12·64 | 11·55 |
| $5\frac{1}{2}$ | 139·7 | 28·55 | 26·43 | 24·62 | 22·83 | 21·05 | 19·29 | 17·54 | 16·09 | 14·65 | 13·22 | 12·08 |
| $5\frac{3}{4}$ | 146·0 | 29·76 | 27·55 | 25·67 | 23·81 | 21·96 | 20·12 | 18·30 | 16·79 | 15·29 | 13·80 | 12·62 |
| 6 | 152·4 | 30·97 | 28·68 | 26·72 | 24·79 | 22·86 | 20·95 | 19·06 | 17·49 | 15·93 | 14·38 | 13·15 |
| $6\frac{1}{4}$ | 158·7 | 32·18 | 29·80 | 27·78 | 25·77 | 23·77 | 21·79 | 19·82 | 18·19 | 16·57 | 14·96 | 13·68 |
| $6\frac{1}{2}$ | 165·1 | 33·39 | 30·93 | 28·83 | 26·75 | 24·68 | 22·62 | 20·58 | 18·89 | 17·21 | 15·54 | 14·21 |

*Note to Table.*—If the External Diameter is given, subtract
Weight per Lineal Foot of a Copper Tube 2 ins. external

WIRE GAUGE, 1884 (The Broughton Copper Company).
the specific gravity, 8·8917.

OF COPPER.

| 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0·160 | 0·144 | 0·128 | 0·116 | 0·104 | 0·092 | 0·080 | 0·072 | 0·064 | 0·056 | 0·048 | 0·040 | 0·036 |
| $\frac{5}{32}$ *f* | $\frac{9}{64}$ *f* | $\frac{1}{8}$ *f* | $\frac{7}{64}$ *f* | $\frac{7}{64}$ *b* | $\frac{3}{32}$ | $\frac{5}{64}$ *f* | $\frac{5}{64}$ *b* | $\frac{1}{16}$ *f* | $\frac{1}{16}$ *b* | $\frac{3}{64}$ *f* | $\frac{3}{64}$ *b* | $\frac{1}{32}$ *f* |
| 4·064 | 3·658 | 3·251 | 2·946 | 2·642 | 2·337 | 2·032 | 1·829 | 1·626 | 1·422 | 1·219 | 1·016 | 0·914 |

FOOT IN POUNDS.

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0·55 | 0·47 | 0·39 | 0·34 | 0·29 | 0·24 | 0·20 | 0·17 | 0·15 | 0·12 | 0·10 | 0·08 | 0·07 |
| 0·79 | 0·69 | 0·58 | 0·51 | 0·44 | 0·38 | 0·32 | 0·28 | 0·24 | 0·21 | 0·17 | 0·14 | 0·12 |
| 1·04 | 0·90 | 0·78 | 0·69 | 0·60 | 0·52 | 0·44 | 0·39 | 0·34 | 0·29 | 0·25 | 0·20 | 0·18 |
| 1·28 | 1·12 | 0·97 | 0·86 | 0·76 | 0·66 | 0·56 | 0·50 | 0·44 | 0·38 | 0·32 | 0·26 | 0·23 |
| 1·52 | 1·34 | 1·17 | 1·04 | 0·92 | 0·80 | 0·68 | 0·61 | 0·53 | 0·46 | 0·39 | 0·32 | 0·29 |
| 1·76 | 1·56 | 1·36 | 1·21 | 1·07 | 0·94 | 0·80 | 0·72 | 0·63 | 0·55 | 0·46 | 0·38 | 0·34 |
| 2·00 | 1·77 | 1·55 | 1·39 | 1·23 | 1·08 | 0·92 | 0·82 | 0·73 | 0·63 | 0·54 | 0·44 | 0·40 |
| 2·24 | 1·99 | 1·75 | 1·57 | 1·39 | 1·21 | 1·04 | 0·93 | 0·82 | 0·71 | 0·61 | 0·50 | 0·45 |
| 2·49 | 2·21 | 1·94 | 1·74 | 1·55 | 1·35 | 1·17 | 1·04 | 0·92 | 0·80 | 0·68 | 0·56 | 0·51 |
| 2·73 | 2·43 | 2·13 | 1·92 | 1·70 | 1·49 | 1·29 | 1·15 | 1·02 | 0·88 | 0·75 | 0·62 | 0·56 |
| 2·97 | 2·65 | 2·33 | 2·09 | 1·86 | 1·63 | 1·41 | 1·26 | 1·11 | 0·97 | 0·83 | 0·68 | 0·61 |
| 3·21 | 2·86 | 2·52 | 2·27 | 2·02 | 1·77 | 1·53 | 1·37 | 1·21 | 1·05 | 0·90 | 0·74 | 0·67 |
| 3·45 | 3·08 | 2·71 | 2·44 | 2·17 | 1·91 | 1·65 | 1·48 | 1·31 | 1·14 | 0·97 | 0·81 | 0·72 |
| 3·70 | 3·30 | 2·91 | 2·62 | 2·33 | 2·05 | 1·77 | 1·59 | 1·40 | 1·22 | 1·04 | 0·87 | 0·78 |
| 3·94 | 3·52 | 3·10 | 2·79 | 2·49 | 2·19 | 1·89 | 1·70 | 1·50 | 1·31 | 1·12 | 0·93 | 0·83 |
| 4·18 | 3·73 | 3·29 | 2·97 | 2·65 | 2·33 | 2·01 | 1·80 | 1·60 | 1·39 | 1·19 | 0·99 | 0·89 |
| 4·42 | 3·95 | 3·49 | 3·14 | 2·80 | 2·47 | 2·13 | 1·91 | 1·69 | 1·48 | 1·26 | 1·05 | 0·94 |
| 4·66 | 4·17 | 3·68 | 3·32 | 2·96 | 2·61 | 2·25 | 2·02 | 1·79 | 1·56 | 1·33 | 1·11 | 1·00 |
| 4·91 | 4·39 | 3·88 | 3·50 | 3·12 | 2·75 | 2·38 | 2·13 | 1·89 | 1·65 | 1·41 | 1·17 | 1·05 |
| 5·15 | 4·61 | 4·07 | 3·67 | 3·28 | 2·88 | 2·50 | 2·24 | 1·98 | 1·73 | 1·48 | 1·23 | 1·10 |
| 5·39 | 4·82 | 4·26 | 3·85 | 3·43 | 3·02 | 2·62 | 2·35 | 2·08 | 1·82 | 1·55 | 1·29 | 1·16 |
| 5·63 | 5·04 | 4·46 | 4·02 | 3·59 | 3·16 | 2·74 | 2·46 | 2·18 | 1·90 | 1·62 | 1·35 | 1·21 |
| 5·87 | 5·26 | 4·65 | 4·20 | 3·75 | 3·30 | 2·86 | 2·57 | 2·27 | 1·99 | 1·70 | 1·41 | 1·27 |
| 6·12 | 5·48 | 4·84 | 4·37 | 3·90 | 3·44 | 2·98 | 2·68 | 2·37 | 2·07 | 1·77 | 1·47 | 1·32 |
| 6·60 | 5·91 | 5·23 | 4·72 | 4·22 | 3·72 | 3·22 | 2·89 | 2·57 | 2·24 | 1·91 | 1·59 | 1·43 |
| 7·08 | 6·35 | 5·62 | 5·07 | 4·53 | 4·00 | 3·46 | 3·11 | 2·76 | 2·41 | 2·06 | 1·71 | 1·54 |
| 7·57 | 6·78 | 6·00 | 5·42 | 4·85 | 4·28 | 3·71 | 3·33 | 2·95 | 2·58 | 2·20 | 1·83 | 1·65 |
| 8·06 | 7·22 | 6·30 | 5·77 | 5·16 | 4·55 | 3·95 | 3·55 | 3·15 | 2·75 | 2·35 | 1·95 | 1·76 |
| 8·54 | 7·65 | 6·78 | 6·13 | 5·48 | 4·83 | 4·19 | 3·76 | 3·34 | 2·92 | 2·50 | 2·08 | 1·87 |
| 9·02 | 8·09 | 7·17 | 6·48 | 5·79 | 5·11 | 4·43 | 3·98 | 3·53 | 3·09 | 2·64 | 2·20 | 1·97 |
| 9·50 | 8·53 | 7·55 | 6·83 | 6·11 | 5·39 | 4·67 | 4·20 | 3·73 | 3·26 | 2·79 | 2·32 | 2·08 |
| 9·99 | 8·96 | 7·94 | 7·18 | 6·42 | 5·67 | 4·92 | 4·42 | 3·92 | 3·42 | 2·93 | 2·44 | 2·19 |
| 10·47 | 9·40 | 8·33 | 7·53 | 6·74 | 5·95 | 5·16 | 4·64 | 4·11 | 3·59 | 3·08 | 2·56 | ... |
| 10·96 | 9·83 | 8·71 | 7·88 | 7·05 | 6·22 | 5·40 | 4·85 | 4·31 | 3·76 | 3·22 | 2·68 | ... |
| 11·44 | 10·27 | 9·10 | 8·23 | 7·36 | 6·50 | 5·64 | 5·07 | 4·50 | 3·93 | 3·37 | 2·80 | ... |
| 11·92 | 10·70 | 9·49 | 8·58 | 7·68 | 6·78 | 5·88 | 5·29 | 4·69 | 4·10 | 3·51 | 2·92 | ... |
| 12·41 | 11·14 | 9·88 | 8·93 | 7·99 | 7·06 | 6·13 | 5·51 | 4·89 | 4·27 | 3·66 | ... | ... |
| 12·89 | 11·57 | 10·26 | 9·28 | 8·31 | 7·34 | 6·37 | 5·72 | 5·08 | 4·44 | 3·80 | ... | ... |

number at bottom of column, pages 304, 305. For example—The diameter, 12 I. W. G., is 2·65 − 0·26 = 2·39 lbs. *f*, full; *b*, bare.

## TABLE 161.—WEIGHT OF SEAMLESS COPPER TUBES : IMPERIAL

Calculated on the basis of

| 1884. | | THICKNESS | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| I. W. G. | | 0000 | 000 | 00 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Inches. | | 0·400 | 0·372 | 0·348 | 0·324 | 0·300 | 0·276 | 0·252 | 0·232 | 0·212 | 0·192 | 0·176 |
| | | $\frac{13}{32}$ *b* | $\frac{3}{8}$ *b* | $\frac{11}{32}$ *f* | $\frac{21}{64}$ *b* | $\frac{19}{64}$ *f* | $\frac{9}{32}$ *b* | $\frac{1}{4}$ *f* | $\frac{15}{64}$ *b* | $\frac{7}{32}$ *b* | $\frac{3}{16}$ *f* | $\frac{11}{64}$ *f* |
| Millimetres. | | 10·160 | 9·449 | 8·839 | 8·229 | 7·620 | 7·010 | 6·401 | 5·893 | 5·385 | 4·877 | 4·470 |
| Internal Diameter. | | WEIGHT OF A LINEAL | | | | | | | | | | |
| Inches. | Millim. | | | | | | | | | | | |
| 6¾ | 171·4 | 34·60 | 32·05 | 29·88 | 27·73 | 25·59 | 23·46 | 21·35 | 19·60 | 17·85 | 16·12 | 14·75 |
| 7 | 177·8 | 35·81 | 33·18 | 30·93 | 28·71 | 26·49 | 24·29 | 22·11 | 20·30 | 18·50 | 16·70 | 15·28 |
| 7¼ | 184·1 | 37·02 | 34·30 | 31·99 | 29·69 | 27·40 | 25·13 | 22·87 | 21·00 | 19·14 | 17·29 | 15·81 |
| 7½ | 190·5 | 38·23 | 35·43 | 33·04 | 30·67 | 28·31 | 25·96 | 23·63 | 21·70 | 19·78 | 17·87 | 16·34 |
| 7¾ | 196·8 | 39·44 | 36·55 | 34·09 | 31·65 | 29·22 | 26·80 | 24·39 | 22·40 | 20·42 | 18·45 | 16·88 |
| 8 | 203·2 | 40·65 | 37·68 | 35·14 | 32·63 | 30·12 | 27·63 | 25·16 | 23·10 | 21·06 | 19·03 | 17·41 |
| 8¼ | 209·5 | 41·86 | 38·80 | 36·20 | 33·61 | 31·03 | 28·47 | 25·92 | 23·81 | 21·70 | 19·61 | 17·94 |
| 8½ | 215·9 | 43·07 | 39·93 | 37·25 | 34·59 | 31·94 | 29·30 | 26·68 | 24·51 | 22·34 | 20·19 | 18·47 |
| 8¾ | 222·2 | 44·28 | 41·05 | 38·30 | 35·57 | 32·84 | 30·14 | 27·44 | 25·21 | 22·98 | 20·77 | 19·00 |
| 9 | 228·6 | 45·49 | 42·18 | 39·35 | 36·55 | 33·75 | 30·97 | 28·21 | 25·91 | 23·63 | 21·35 | 19·54 |
| 9¼ | 234·9 | 46·70 | 43·30 | 40·41 | 37·53 | 34·66 | 31·81 | 28·97 | 26·61 | 24·27 | 21·93 | 20·07 |
| 9½ | 241·3 | 47·91 | 44·43 | 41·46 | 38·51 | 35·57 | 32·64 | 29·73 | 27·31 | 24·91 | 22·51 | 20·60 |
| 9¾ | 247·6 | 49·12 | 45·55 | 42·51 | 39·49 | 36·47 | 33·48 | 30·49 | 28·02 | 25·55 | 23·09 | 21·13 |
| 10 | 254·0 | 50·33 | 46·68 | 43·56 | 40·47 | 37·38 | 34·31 | 31·25 | 28·72 | 26·19 | 23·67 | 21·67 |
| 10¼ | 260·3 | 51·54 | 47·80 | 44·62 | 41·45 | 38·29 | 35·15 | 32·02 | 29·42 | 26·83 | 24·25 | 22·20 |
| 10½ | 266·7 | 52·75 | 48·93 | 45·67 | 42·43 | 39·20 | 35·98 | 32·78 | 30·12 | 27·47 | 24·83 | 22·73 |
| 10¾ | 273·0 | 53·96 | 50·05 | 46·72 | 43·41 | 40·10 | 36·81 | 33·54 | 30·82 | 28·11 | 25·42 | 23·26 |
| 11 | 279·4 | 55·16 | 51·18 | 47·77 | 44·39 | 41·01 | 37·65 | 34·30 | 31·52 | 28·75 | 26·00 | 23·80 |
| 11¼ | 285·7 | 56·37 | 52·30 | 48·83 | 45·37 | 41·92 | 38·48 | 35·06 | 32·23 | 29·40 | 26·58 | 24·33 |
| 11½ | 292·1 | 57·58 | 53·43 | 49·88 | 46·35 | 42·83 | 39·32 | 35·83 | 32·93 | 30·04 | 27·16 | 24·86 |
| 11¾ | 298·4 | 58·79 | 54·55 | 50·93 | 47·33 | 43·73 | 40·15 | 36·59 | 33·63 | 30·68 | 27·74 | 25·39 |
| 12 | 304·8 | 60·00 | 55·68 | 51·98 | 48·31 | 44·64 | 40·99 | 37·35 | 34·33 | 31·32 | 28·32 | 25·92 |
| 12¼ | 311·1 | 61·21 | 56·80 | 53·04 | 49·29 | 45·55 | 41·82 | 38·11 | 35·03 | 31·96 | 28·90 | 26·46 |
| 12½ | 317·5 | 62·42 | 57·93 | 54·09 | 50·26 | 46·45 | 42·66 | 38·88 | 35·73 | 32·60 | 29·48 | 26·99 |
| 12¾ | 323·8 | 63·63 | 59·05 | 55·14 | 51·24 | 47·36 | 43·49 | 39·64 | 36·44 | 33·24 | 30·06 | 27·52 |
| 13 | 330·2 | 64·84 | 60·18 | 56·19 | 52·22 | 48·27 | 44·33 | 40·40 | 37·14 | 33·88 | 30·64 | 28·05 |
| 13¼ | 336·5 | 66·05 | 61·30 | 57·25 | 53·20 | 49·18 | 45·16 | 41·16 | 37·84 | 34·53 | 31·22 | 28·59 |
| 13½ | 342·9 | 67·26 | 62·43 | 58·30 | 54·18 | 50·08 | 46·00 | 41·92 | 38·54 | 35·17 | 31·80 | 29·12 |
| 13¾ | 349·2 | 68·47 | 63·55 | 59·35 | 55·16 | 50·99 | 46·83 | 42·69 | 39·24 | 35·81 | 32·38 | 29·65 |
| 14 | 355·6 | 69·68 | 64·68 | 60·40 | 56·14 | 51·90 | 47·67 | 43·45 | 39·94 | 36·45 | 32·96 | 30·18 |
| | | 3·87 | 3·35 | 2·93 | 2·54 | 2·18 | 1·84 | 1·54 | 1·30 | 1·09 | 0·89 | 0·75 |

*Note to Table.*—If the External Diameter is given, subtract Lineal Foot of a Copper Tube 2 ins. external diameter,

WIRE GAUGE, 1884 (The Broughton Copper Co.) (*continued*).

the specific gravity, 8·8917.

OF COPPER.

| | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0·160 | 0·144 | 0·128 | 0·116 | 0·104 | 0·092 | 0·080 | 0·072 | 0·064 | 0·056 | 0·048 | 0·040 | 0·036 |
| | $\frac{5}{32}$ *f* | $\frac{9}{64}$ *f* | $\frac{1}{8}$ *f* | $\frac{7}{64}$ *f* | $\frac{7}{64}$ *b* | $\frac{3}{32}$ | $\frac{5}{64}$ *f* | $\frac{5}{64}$ *b* | $\frac{1}{16}$ *f* | $\frac{1}{16}$ *b* | $\frac{3}{64}$ *f* | $\frac{3}{64}$ *b* | $\frac{1}{32}$ *f* |
| | 4·064 | 3·658 | 3·251 | 2·946 | 2·642 | 2·337 | 2·032 | 1·829 | 1·626 | 1·422 | 1·219 | 1·016 | 0·914 |
| FOOT IN POUNDS. | | | | | | | | | | | | | |
| | 13·37 | 12·01 | 10·65 | 9·63 | 8·62 | 7·61 | 6·61 | 5·94 | 5·28 | 4·61 | 3·95 | ... | ... |
| | 13·86 | 12·44 | 11·04 | 9·99 | 8·94 | 7·89 | 6·85 | 6·16 | 5·47 | 4·78 | 4·09 | ... | ... |
| | 14·34 | 12·88 | 11·42 | 10·34 | 9·25 | 8·17 | 7·09 | 6·38 | 5·66 | 4·95 | ... | ... | ... |
| | 14·83 | 13·32 | 11·81 | 10·69 | 9·57 | 8·45 | 7·34 | 6·60 | 5·86 | 5·12 | ... | ... | ... |
| | 15·31 | 13·75 | 12·20 | 11·04 | 9·88 | 8·73 | 7·58 | 6·81 | 6·05 | 5·29 | ... | ... | ... |
| | 15·79 | 14·19 | 12·59 | 11·39 | 10·20 | 9·01 | 7·82 | 7·03 | 6·24 | 5·46 | ... | ... | ... |
| | 16·28 | 14·62 | 12·97 | 11·74 | 10·51 | 9·28 | 8·06 | 7·25 | 6·44 | ... | ... | ... | ... |
| | 16·76 | 15·06 | 13·36 | 12·09 | 10·82 | 9·56 | 8·30 | 7·47 | 6·63 | ... | ... | ... | ... |
| | 17·25 | 15·49 | 13·75 | 12·44 | 11·14 | 9·84 | 8·55 | 7·68 | 6·82 | ... | ... | ... | ... |
| | 17·73 | 15·93 | 14·13 | 12·79 | 11·45 | 10·12 | 8·79 | 7·90 | 7·02 | ... | ... | ... | ... |
| | 18·21 | 16·36 | 14·52 | 13·14 | 11·77 | 10·40 | 9·03 | 8·12 | ... | ... | ... | ... | ... |
| | 18·70 | 16·80 | 14·91 | 13·49 | 12·08 | 10·68 | 9·27 | 8·34 | ... | ... | ... | ... | ... |
| | 19·18 | 17·24 | 15·30 | 13·84 | 12·40 | 10·95 | 9·51 | 8·55 | ... | ... | ... | ... | ... |
| | 19·67 | 17·67 | 15·68 | 14·20 | 12·71 | 11·23 | 9·76 | 8·77 | ... | ... | ... | ... | ... |
| | 20·15 | 18·11 | 16·07 | 14·55 | 13·03 | 11·51 | 10·00 | ... | ... | ... | ... | ... | ... |
| | 20·63 | 18·54 | 16·46 | 14·90 | 13·34 | 11·79 | 10·24 | ... | ... | ... | ... | ... | ... |
| | 21·12 | 18·98 | 16·84 | 15·25 | 13·66 | 12·07 | 10·48 | ... | ... | ... | ... | ... | ... |
| | 21·60 | 19·41 | 17·23 | 15·60 | 13·97 | 12·34 | 10·72 | ... | ... | ... | ... | ... | ... |
| | 22·08 | 19·85 | 17·62 | 15·95 | 14·28 | 12·62 | ... | ... | ... | ... | ... | ... | ... |
| | 22·57 | 20·28 | 18·01 | 16·30 | 14·60 | 12·90 | ... | ... | ... | ... | ... | ... | ... |
| | 23·05 | 20·72 | 18·39 | 16·65 | 14·91 | 13·18 | ... | ... | ... | ... | ... | ... | ... |
| | 23·54 | 21·16 | 18·78 | 17·00 | 15·23 | 13·46 | ... | ... | ... | ... | ... | ... | ... |
| | 24·02 | 21·59 | 19·17 | 17·35 | 15·54 | ... | ... | ... | ... | ... | ... | ... | ... |
| | 24·50 | 22·03 | 19·55 | 17·70 | 15·86 | ... | ... | ... | ... | ... | ... | ... | ... |
| | 24·99 | 22·46 | 19·94 | 18·05 | 16·17 | ... | ... | ... | ... | ... | ... | ... | ... |
| | 25·47 | 22·90 | 20·33 | 18·41 | 16·49 | ... | ... | ... | ... | ... | ... | ... | ... |
| | 25·96 | 23·33 | 20·72 | 18·76 | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| | 26·44 | 23·77 | 21·10 | 19·11 | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| | 26·92 | 24·20 | 21·49 | 19·46 | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| | 27·41 | 24·64 | 21·88 | 19·81 | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| | 0·62 | 0·50 | 0·40 | 0·33 | 0·26 | 0·20 | 0·15 | 0·12 | 0·10 | 0·08 | 0·06 | 0·04 | 0·03 |

number at bottom of column ; for example—The Weight per 12 I. W. G., is 2·65 -- 0·26 = 2·39 lbs. *f*, full ; *b*, bare.

TABLE 162.—WEIGHT OF SEAMLESS COPPER TUBES:

Calculated on the basis of

| | | THICKNESS | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| B. W. G. | | 0000 | 000 | 00 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Inches. | | 0·454 | 0·425 | 0·380 | 0·340 | 0·300 | 0·284 | 0·259 | 0·238 | 0·220 | 0·203 | 0·180 |
| | | $\frac{29}{64}$ | $\frac{27}{64}$ *f* | $\frac{3}{8}$ *f* | $\frac{11}{32}$ | $\frac{19}{64}$ *f* | $\frac{9}{32}$ *f* | $\frac{1}{4}$ *f* | $\frac{15}{64}$ *f* | $\frac{7}{32}$ *f* | $\frac{13}{64}$ | $\frac{3}{16}$ *b* |
| Millimetres. | | 11·53 | 10·79 | 9·65 | 8·64 | 7·62 | 7·21 | 6·58 | 6·04 | 5·59 | 5·16 | 4·57 |
| Internal Diameter. | | WEIGHT OF A LINEAL | | | | | | | | | | |
| Inches. | Millim. | | | | | | | | | | | |
| $\frac{1}{8}$ | 3·2 | 3·18 | 2·83 | 2·32 | 1·91 | 1·54 | 1·40 | 1·20 | 1·04 | 0·92 | 0·80 | 0·66 |
| $\frac{1}{4}$ | 6·3 | 3·87 | 3·47 | 2·90 | 2·43 | 2·00 | 1·83 | 1·59 | 1·40 | 1·25 | 1·11 | 0·94 |
| $\frac{3}{8}$ | 9·5 | 4·55 | 4·11 | 3·47 | 2·94 | 2·45 | 2·26 | 1·99 | 1·76 | 1·58 | 1·42 | 1·21 |
| $\frac{1}{2}$ | 12·7 | 5·24 | 4·76 | 4·04 | 3·45 | 2·90 | 2·69 | 2·38 | 2·12 | 1·92 | 1·73 | 1·48 |
| $\frac{5}{8}$ | 15·9 | 5·92 | 5·40 | 4·62 | 3·97 | 3·36 | 3·12 | 2·77 | 2·48 | 2·25 | 2·03 | 1·75 |
| $\frac{3}{4}$ | 19·0 | 6·61 | 6·04 | 5·19 | 4·48 | 3·81 | 3·55 | 3·16 | 2·84 | 2·58 | 2·34 | 2·02 |
| $\frac{7}{8}$ | 22·2 | 7·30 | 6·68 | 5·77 | 5·00 | 4·26 | 3·98 | 3·55 | 3·20 | 2·91 | 2·65 | 2·30 |
| 1 | 25·4 | 7·99 | 7·33 | 6·34 | 5·51 | 4·72 | 4·41 | 3·94 | 3·56 | 3·25 | 2·95 | 2·57 |
| $1\frac{1}{8}$ | 28·6 | 8·67 | 7·97 | 6·92 | 6·03 | 5·17 | 4·84 | 4·34 | 3·92 | 3·58 | 3·26 | 2·84 |
| $1\frac{1}{4}$ | 31·7 | 9·36 | 8·61 | 7·49 | 6·54 | 5·62 | 5·27 | 4·73 | 4·28 | 3·91 | 3·57 | 3·11 |
| $1\frac{3}{8}$ | 34·9 | 10·04 | 9·25 | 8·07 | 7·05 | 6·08 | 5·70 | 5·12 | 4·64 | 4·24 | 3·87 | 3·39 |
| $1\frac{1}{2}$ | 38·1 | 10·73 | 9·90 | 8·64 | 7·57 | 6·53 | 6·13 | 5·51 | 5·00 | 4·58 | 4·18 | 3·66 |
| $1\frac{5}{8}$ | 41·3 | 11·42 | 10·54 | 9·22 | 8·08 | 6·99 | 6·56 | 5·90 | 5·36 | 4·91 | 4·49 | 3·93 |
| $1\frac{3}{4}$ | 44·4 | 12·10 | 11·18 | 9·79 | 8·60 | 7·44 | 6·99 | 6·29 | 5·72 | 5·24 | 4·80 | 4·20 |
| $1\frac{7}{8}$ | 47·6 | 12·79 | 11·82 | 10·37 | 9·11 | 7·89 | 7·42 | 6·69 | 6·08 | 5·58 | 5·10 | 4·47 |
| 2 | 50·8 | 13·48 | 12·47 | 10·94 | 9·62 | 8·35 | 7·85 | 7·08 | 6·44 | 5·91 | 5·41 | 4·75 |
| $2\frac{1}{8}$ | 54·0 | 14·16 | 13·11 | 11·52 | 10·14 | 8·80 | 8·28 | 7·47 | 6·80 | 6·24 | 5·72 | 5·02 |
| $2\frac{1}{4}$ | 57·1 | 14·85 | 13·75 | 12·09 | 10·65 | 9·25 | 8·71 | 7·86 | 7·16 | 6·57 | 6·02 | 5·29 |
| $2\frac{3}{8}$ | 60·3 | 15·54 | 14·40 | 12·66 | 11·17 | 9·71 | 9·14 | 8·25 | 7·52 | 6·91 | 6·33 | 5·56 |
| $2\frac{1}{2}$ | 63·5 | 16·22 | 15·04 | 13·24 | 11·68 | 10·16 | 9·56 | 8·64 | 7·88 | 7·24 | 6·64 | 5·84 |
| $2\frac{5}{8}$ | 66·7 | 16·91 | 15·68 | 13·81 | 12·20 | 10·62 | 9·99 | 9·04 | 8·24 | 7·57 | 6·94 | 6·11 |
| $2\frac{3}{4}$ | 69·8 | 17·60 | 16·32 | 14·39 | 12·71 | 11·07 | 10·42 | 9·43 | 8·60 | 7·90 | 7·25 | 6·38 |
| $2\frac{7}{8}$ | 73·0 | 18·28 | 16·97 | 14·96 | 13·22 | 11·52 | 10·85 | 9·82 | 8·96 | 8·24 | 7·56 | 6·65 |
| 3 | 76·2 | 18·97 | 17·61 | 15·54 | 13·74 | 11·98 | 11·28 | 10·21 | 9·32 | 8·57 | 7·87 | 6·92 |
| $3\frac{1}{4}$ | 82·5 | 20·34 | 18·89 | 16·69 | 14·77 | 12·88 | 12·14 | 10·99 | 10·04 | 9·23 | 8·48 | 7·47 |
| $3\frac{1}{2}$ | 88·9 | 21·72 | 20·18 | 17·84 | 15·79 | 13·79 | 13·00 | 11·78 | 10·76 | 9·90 | 9·09 | 8·01 |
| $3\frac{3}{4}$ | 95·2 | 23·09 | 21·47 | 18·99 | 16·82 | 14·70 | 13·86 | 12·56 | 11·48 | 10·57 | 9·71 | 8·56 |
| 4 | 101·6 | 24·46 | 22·75 | 20·13 | 17·85 | 15·61 | 14·72 | 13·34 | 12·20 | 11·23 | 10·32 | 9·10 |
| $4\frac{1}{4}$ | 107·9 | 25·84 | 24·04 | 21·28 | 18·88 | 16·51 | 15·58 | 14·13 | 12·92 | 11·90 | 10·94 | 9·65 |
| $4\frac{1}{2}$ | 114·3 | 27·21 | 25·32 | 22·43 | 19·91 | 17·42 | 16·44 | 14·91 | 13·64 | 12·56 | 11·55 | 10·19 |
| $4\frac{3}{4}$ | 120·6 | 28·58 | 26·61 | 23·58 | 20·94 | 18·33 | 17·29 | 15·69 | 14·36 | 13·23 | 12·16 | 10·73 |
| 5 | 127·0 | 29·95 | 27·89 | 24·73 | 21·96 | 19·23 | 18·15 | 16·48 | 15·08 | 13·89 | 12·78 | 11·28 |
| $5\frac{1}{4}$ | 133·3 | 31·33 | 29·18 | 25·88 | 22·99 | 20·14 | 19·01 | 17·26 | 15·80 | 14·56 | 13·39 | 11·82 |
| $5\frac{1}{2}$ | 139·7 | 32·70 | 30·46 | 27·03 | 24·02 | 21·05 | 19·87 | 18·04 | 16·52 | 15·22 | 14·01 | 12·37 |
| $5\frac{3}{4}$ | 146·0 | 34·07 | 31·75 | 28·18 | 25·05 | 21·96 | 20·73 | 18·83 | 17·24 | 15·89 | 14·62 | 12·91 |
| 6 | 152·4 | 35·45 | 33·03 | 29·33 | 26·08 | 22·86 | 21·59 | 19·61 | 17·96 | 16·55 | 15·23 | 13·46 |
| $6\frac{1}{4}$ | 158·7 | 36·82 | 34·32 | 30·48 | 27·11 | 23·77 | 22·45 | 20·39 | 18·68 | 17·22 | 15·85 | 14·00 |
| $6\frac{1}{2}$ | 165·1 | 38·19 | 35·60 | 31·63 | 28·13 | 24·68 | 23·31 | 21·18 | 19·40 | 17·88 | 16·46 | 14·55 |

*Note to Table.*—If the External Diameter is given, subtract
The Weight per Lineal Foot of a Copper Tube 2 ins. external

**Birmingham Wire Gauge** (The Broughton Copper Co.).
the specific gravity, 8·8917.

of Copper.

| 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0·165 | 0·148 | 0·134 | 0·120 | 0·109 | 0·095 | 0·083 | 0·072 | 0·065 | 0·058 | 0·049 | 0·042 | 0·035 |
| $\frac{11}{64}$ *b* | $\frac{9}{64}$ *f* | $\frac{9}{64}$ *b* | $\frac{1}{8}$ *b* | $\frac{7}{64}$ | $\frac{3}{32}$ *f* | $\frac{5}{64}$ *f* | $\frac{5}{64}$ *b* | $\frac{1}{16}$ *f* | $\frac{1}{16}$ *b* | $\frac{3}{64}$ *f* | $\frac{3}{64}$ *b* | $\frac{1}{32}$ *f* |
| 4·19 | 3·76 | 3·40 | 3·05 | 2·77 | 2·41 | 2·11 | 1·83 | 1·65 | 1·47 | 1·24 | 1·07 | 0·89 |

Foot in Pounds.

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0·58 | 0·49 | 0·42 | 0·36 | 0·31 | 0·25 | 0·21 | 0·17 | 0·15 | 0·13 | 0·10 | 0·08 | 0·07 |
| 0·83 | 0·71 | 0·62 | 0·54 | 0·47 | 0·40 | 0·33 | 0·28 | 0·25 | 0·22 | 0·18 | 0·15 | 0·12 |
| 1·08 | 0·94 | 0·82 | 0·72 | 0·64 | 0·54 | 0·46 | 0·39 | 0·35 | 0·30 | 0·25 | 0·21 | 0·17 |
| 1·33 | 1·16 | 1·03 | 0·90 | 0·80 | 0·68 | 0·58 | 0·50 | 0·44 | 0·39 | 0·32 | 0·27 | 0·23 |
| 1·58 | 1·38 | 1·23 | 1·08 | 0·97 | 0·83 | 0·71 | 0·61 | 0·54 | 0·48 | 0·40 | 0·34 | 0·28 |
| 1·83 | 1·61 | 1·43 | 1·26 | 1·13 | 0·97 | 0·84 | 0·72 | 0·64 | 0·57 | 0·47 | 0·40 | 0·33 |
| 2·08 | 1·83 | 1·64 | 1·44 | 1·30 | 1·11 | 0·96 | 0·82 | 0·74 | 0·65 | 0·55 | 0·47 | 0·38 |
| 2·32 | 2·05 | 1·84 | 1·63 | 1·46 | 1·26 | 1·09 | 0·93 | 0·84 | 0·74 | 0·62 | 0·53 | 0·44 |
| 2·57 | 2·28 | 2·04 | 1·81 | 1·63 | 1·40 | 1·21 | 1·04 | 0·94 | 0·83 | 0·70 | 0·59 | 0·49 |
| 2·82 | 2·50 | 2·24 | 1·99 | 1·79 | 1·55 | 1·34 | 1·15 | 1·03 | 0·92 | 0·77 | 0·66 | 0·54 |
| 3·07 | 2·73 | 2·45 | 2·17 | 1·96 | 1·69 | 1·46 | 1·26 | 1·13 | 1·00 | 0·84 | 0·72 | 0·60 |
| 3·32 | 2·95 | 2·65 | 2·35 | 2·12 | 1·83 | 1·59 | 1·37 | 1·23 | 1·09 | 0·92 | 0·78 | 0·65 |
| 3·57 | 3·17 | 2·85 | 2·53 | 2·29 | 1·98 | 1·71 | 1·48 | 1·33 | 1·18 | 0·99 | 0·85 | 0·70 |
| 3·82 | 3·40 | 3·05 | 2·71 | 2·45 | 2·12 | 1·84 | 1·59 | 1·43 | 1·27 | 1·07 | 0·91 | 0·76 |
| 4·07 | 3·62 | 3·26 | 2·90 | 2·62 | 2·26 | 1·97 | 1·70 | 1·52 | 1·36 | 1·14 | 0·97 | 0·81 |
| 4·32 | 3·85 | 3·46 | 3·08 | 2·78 | 2·41 | 2·09 | 1·80 | 1·62 | 1·44 | 1·21 | 1·04 | 0·86 |
| 4·57 | 4·07 | 3·66 | 3·26 | 2·95 | 2·55 | 2·22 | 1·91 | 1·72 | 1·53 | 1·29 | 1·10 | 0·91 |
| 4·82 | 4·29 | 3·86 | 3·44 | 3·11 | 2·69 | 2·34 | 2·02 | 1·82 | 1·62 | 1·36 | 1·16 | 0·97 |
| 5·07 | 4·52 | 4·07 | 3·62 | 3·27 | 2·84 | 2·47 | 2·13 | 1·92 | 1·71 | 1·44 | 1·23 | 1·02 |
| 5·32 | 4·74 | 4·27 | 3·80 | 3·44 | 2·98 | 2·59 | 2·24 | 2·02 | 1·79 | 1·51 | 1·29 | 1·07 |
| 5·57 | 4·96 | 4·47 | 3·98 | 3·60 | 3·13 | 2·72 | 2·35 | 2·11 | 1·88 | 1·58 | 1·35 | 1·13 |
| 5·82 | 5·19 | 4·67 | 4·17 | 3·77 | 3·27 | 2·84 | 2·46 | 2·21 | 1·97 | 1·66 | 1·42 | 1·18 |
| 6·07 | 5·41 | 4·88 | 4·35 | 3·93 | 3·41 | 2·97 | 2·57 | 2·31 | 2·06 | 1·73 | 1·48 | 1·23 |
| 6·32 | 5·64 | 5·08 | 4·53 | 4·10 | 3·56 | 3·10 | 2·68 | 2·41 | 2·15 | 1·81 | 1·55 | 1·28 |
| 6·82 | 6·08 | 5·49 | 4·89 | 4·43 | 3·84 | 3·35 | 2·89 | 2·61 | 2·32 | 1·96 | 1·67 | 1·39 |
| 7·32 | 6·53 | 5·89 | 5·25 | 4·76 | 4·13 | 3·60 | 3·11 | 2·80 | 2·50 | 2·10 | 1·80 | 1·50 |
| 7·81 | 6·9[illegible] | 6·30 | 5·62 | 5·09 | 4·42 | 3·85 | 3·33 | 3·00 | 2·67 | 2·25 | 1·93 | 1·60 |
| 8·31 | 7·43 | 6·70 | 5·98 | 5·42 | 4·71 | 4·10 | 3·55 | 3·20 | 2·85 | 2·40 | 2·05 | 1·71 |
| 8·81 | 7·87 | 7·11 | 6·34 | 5·75 | 4·99 | 4·35 | 3·76 | 3·39 | 3·02 | 2·55 | 2·18 | 1·81 |
| 9·31 | 8·32 | 7·51 | 6·71 | 6·08 | 5·28 | 4·60 | 3·98 | 3·59 | 3·20 | 2·70 | 2·31 | 1·92 |
| 9·81 | 8·77 | 7·92 | 7·07 | 6·41 | 5·57 | 4·85 | 4·20 | 3·79 | 3·37 | 2·84 | 2·43 | 2·03 |
| 10·31 | 9·22 | 8·32 | 7·43 | 6·74 | 5·86 | 5·10 | 4·42 | 3·98 | 3·55 | 2·99 | 2·56 | 2·13 |
| 10·81 | 9·66 | 8·73 | 7·80 | 7·07 | 6·14 | 5·35 | 4·64 | 4·18 | 3·72 | 3·14 | 2·69 | ... |
| 11·31 | 10·11 | 9·13 | 8·16 | 7·40 | 6·43 | 5·61 | 4·85 | 4·38 | 3·90 | 3·29 | 2·82 | ... |
| 11·81 | 10·56 | 9·54 | 8·52 | 7·73 | 6·72 | 5·86 | 5·07 | 4·57 | 4·07 | 3·44 | 2·94 | ... |
| 12·31 | 11·01 | 9·94 | 8·88 | 8·06 | 7·00 | 6·11 | 5·29 | 4·77 | 4·25 | 3·59 | 3·07 | ... |
| 12·80 | 11·45 | 10·35 | 9·25 | 8·38 | 7·29 | 6·36 | 5·51 | 4·97 | 4·43 | 3·73 | ... | ... |
| 13·30 | 11·90 | 10·75 | 9·61 | 8·71 | 7·58 | 6·61 | 5·72 | 5·16 | 4·60 | 3·88 | ... | ... |

number given at bottom of column, pages 308, 309. For example—
diameter, 12 B. W. G., is 2·78 – 0·29 = 2·49 lbs. *f*, full; *b*, bare.

TABLE 162.—WEIGHT OF SEAMLESS COPPER TUBES: BIRMING-

Calculated on the basis of

| | | THICKNESS | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| B. W. G. | | 0000 | 000 | 00 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Inches. | | 0·454 | 0·425 | 0·380 | 0·340 | 0·300 | 0·284 | 0·259 | 0·238 | 0·220 | 0·203 | 0·180 |
| | | $\frac{29}{64}$ | $\frac{27}{64}$ *f* | $\frac{3}{8}$ *f* | $\frac{11}{32}$ | $\frac{19}{64}$ *f* | $\frac{9}{32}$ *f* | $\frac{1}{4}$ *f* | $\frac{15}{64}$ *f* | $\frac{7}{32}$ *f* | $\frac{13}{64}$ | $\frac{3}{16}$ *b* |
| Millimetres. | | 11·53 | 10·79 | 9·65 | 8·64 | 7·62 | 7·21 | 6·58 | 6·04 | 5·59 | 5·16 | 4·57 |
| Internal Diameter. | | WEIGHT OF A LINEAL | | | | | | | | | | |
| Inches. | Millim. | | | | | | | | | | | |
| $6\frac{3}{4}$ | 171·4 | 39·57 | 36·89 | 32·78 | 29·16 | 25·59 | 24·17 | 21·96 | 20·12 | 18·55 | 17·07 | 15·09 |
| 7 | 177·8 | 40·94 | 38·18 | 33·93 | 30·19 | 26·49 | 25·03 | 22·74 | 20·84 | 19·22 | 17·69 | 15·63 |
| $7\frac{1}{4}$ | 184·1 | 42·31 | 39·46 | 35·08 | 31·22 | 27·40 | 25·88 | 23·53 | 21·56 | 19·88 | 18·30 | 16·18 |
| $7\frac{1}{2}$ | 190·5 | 43·69 | 40·75 | 36·22 | 32·25 | 28·31 | 26·74 | 24·31 | 22·28 | 20·55 | 18·92 | 16·72 |
| $7\frac{3}{4}$ | 196·8 | 45·06 | 42·03 | 37·37 | 33·28 | 29·22 | 27·60 | 25·09 | 23·00 | 21·21 | 19·53 | 17·27 |
| 8 | 203·2 | 46·43 | 43·32 | 38·52 | 34·30 | 30·12 | 28·46 | 25·88 | 23·72 | 21·88 | 20·14 | 17·81 |
| $8\frac{1}{4}$ | 209·5 | 47·80 | 44·60 | 39·67 | 35·33 | 31·03 | 29·32 | 26·66 | 24·44 | 22·54 | 20·76 | 18·36 |
| $8\frac{1}{2}$ | 215·9 | 49·18 | 45·89 | 40·82 | 36·36 | 31·94 | 30·18 | 27·44 | 25·16 | 23·21 | 21·37 | 18·90 |
| $8\frac{3}{4}$ | 222·3 | 50·55 | 47·17 | 41·97 | 37·39 | 32·84 | 31·04 | 28·23 | 25·88 | 23·87 | 21·99 | 19·45 |
| 9 | 228·6 | 51·92 | 48·46 | 43·12 | 38·42 | 33·75 | 31·90 | 29·01 | 26·60 | 24·54 | 22·60 | 19·99 |
| $9\frac{1}{4}$ | 235·0 | 53·30 | 49·74 | 44·27 | 39·45 | 34·66 | 32·76 | 29·79 | 27·32 | 25·20 | 23·21 | 20·53 |
| $9\frac{1}{2}$ | 241·3 | 54·67 | 51·03 | 45·42 | 40·47 | 35·57 | 33·61 | 30·58 | 28·04 | 25·87 | 23·83 | 21·08 |
| $9\frac{3}{4}$ | 247·7 | 56·04 | 52·31 | 46·57 | 41·50 | 36·47 | 34·47 | 31·36 | 28·76 | 26·53 | 24·44 | 21·62 |
| 10 | 254·0 | 57·42 | 53·60 | 47·72 | 42·53 | 37·38 | 35·33 | 32·14 | 29·48 | 27·20 | 25·06 | 22·17 |
| $10\frac{1}{4}$ | 260·4 | 58·79 | 54·89 | 48·87 | 43·56 | 38·29 | 36·19 | 32·93 | 30·20 | 27·87 | 25·67 | 22·71 |
| $10\frac{1}{2}$ | 266·7 | 60·16 | 56·17 | 50·02 | 44·59 | 39·20 | 37·05 | 33·71 | 30·92 | 28·53 | 26·28 | 23·26 |
| $10\frac{3}{4}$ | 273·1 | 61·54 | 57·46 | 51·17 | 45·61 | 40·10 | 37·91 | 34·49 | 31·64 | 29·20 | 26·90 | 23·80 |
| 11 | 279·4 | 62·91 | 58·74 | 52·31 | 46·64 | 41·01 | 38·77 | 35·28 | 32·36 | 29·86 | 27·51 | 24·34 |
| $11\frac{1}{4}$ | 285·8 | 64·28 | 60·03 | 53·46 | 47·67 | 41·92 | 39·63 | 36·06 | 33·08 | 30·53 | 28·13 | 24·89 |
| $11\frac{1}{2}$ | 292·1 | 65·65 | 61·31 | 54·61 | 48·70 | 42·83 | 40·49 | 36·84 | 33·80 | 31·19 | 28·74 | 25·43 |
| $11\frac{3}{4}$ | 298·5 | 67·03 | 62·60 | 55·76 | 49·73 | 43·73 | 41·35 | 37·63 | 34·52 | 31·86 | 29·35 | 25·98 |
| 12 | 304·8 | 68·40 | 63·88 | 56·91 | 50·76 | 44·64 | 42·20 | 38·41 | 35·24 | 32·52 | 29·97 | 26·52 |
| $12\frac{1}{4}$ | 311·2 | 69·77 | 65·17 | 58·06 | 51·78 | 45·55 | 43·06 | 39·19 | 35·96 | 33·19 | 30·58 | 27·07 |
| $12\frac{1}{2}$ | 317·5 | 71·15 | 66·45 | 59·21 | 52·81 | 46·45 | 43·92 | 39·98 | 36·68 | 33·85 | 31·20 | 27·61 |
| $12\frac{3}{4}$ | 323·9 | 72·52 | 67·74 | 60·36 | 53·84 | 47·36 | 44·78 | 40·76 | 37·40 | 34·52 | 31·81 | 28·16 |
| 13 | 330·2 | 73·89 | 69·02 | 61·51 | 54·87 | 48·27 | 45·64 | 41·54 | 38·11 | 35·18 | 32·42 | 28·70 |
| $13\frac{1}{4}$ | 336·6 | 75·27 | 70·31 | 62·66 | 55·90 | 49·18 | 46·50 | 42·33 | 38·83 | 35·85 | 33·04 | 29·24 |
| $13\frac{1}{2}$ | 342·9 | 76·64 | 71·59 | 63·81 | 56·93 | 50·08 | 47·36 | 43·11 | 39·55 | 36·52 | 33·65 | 29·79 |
| $13\frac{3}{4}$ | 349·3 | 78·01 | 72·88 | 64·96 | 57·95 | 50·99 | 48·22 | 43·89 | 40·27 | 37·18 | 34·27 | 30·33 |
| 14 | 355·6 | 79·39 | 74·17 | 66·11 | 58·98 | 51·90 | 49·08 | 44·68 | 40·99 | 37·85 | 34·88 | 30·88 |
| | | 4·99 | 4·37 | 3·49 | 2·80 | 2·18 | 1·95 | 1·62 | 1·37 | 1·17 | 1·00 | 0·78 |

*Note to Table.*—If the External Diameter is given, subtract
per Lineal Foot of a Copper Tube 2 ins. external diameter,

HAM WIRE GAUGE (The Broughton Copper Co.) (*continued*).
the specific gravity, 8·8917.

OF COPPER.

| | 8<br>0·165<br>$\frac{11}{64}$ *b*<br>4·19 | 9<br>0·148<br>$\frac{9}{64}$ *f*<br>3·76 | 10<br>0·134<br>$\frac{9}{64}$ *b*<br>3·40 | 11<br>0·120<br>$\frac{1}{8}$ *b*<br>3·05 | 12<br>0·109<br>$\frac{7}{64}$<br>2·77 | 13<br>0·095<br>$\frac{3}{32}$ *f*<br>2·41 | 14<br>0·083<br>$\frac{5}{64}$ *f*<br>2·11 | 15<br>0·072<br>$\frac{5}{64}$ *b*<br>1·83 | 16<br>0·065<br>$\frac{1}{16}$ *f*<br>1·65 | 17<br>0·058<br>$\frac{1}{16}$ *b*<br>1·47 | 18<br>0·049<br>$\frac{3}{64}$ *f*<br>1·24 | 19<br>0·042<br>$\frac{3}{64}$ *b*<br>1·07 | 20<br>0·035<br>$\frac{1}{32}$ *f*<br>0·89 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FOOT IN POUNDS. | | | | | | | | | | | | | |
| | 13·80 | 12·35 | 11·16 | 9·97 | 9·04 | 7·87 | 6·86 | 5·94 | 5·36 | 4·78 | 4·03 | ... | ... |
| | 14·30 | 12·80 | 11·56 | 10·34 | 9·37 | 8·15 | 7·11 | 6·16 | 5·55 | 4·95 | 4·18 | ... | ... |
| | 14·80 | 13·25 | 11·97 | 10·70 | 9·70 | 8·44 | 7·36 | 6·38 | 5·75 | 5·13 | ... | ... | ... |
| | 15·30 | 13·69 | 12·37 | 11·06 | 10·03 | 8·73 | 7·61 | 6·59 | 5·95 | 5·30 | ... | ... | ... |
| | 15·80 | 14·14 | 12·78 | 11·42 | 10·36 | 9·02 | 7·86 | 6·81 | 6·14 | 5·48 | ... | ... | ... |
| | 16·30 | 14·59 | 13·19 | 11·79 | 10·69 | 9·30 | 8·12 | 7·03 | 6·34 | 5·65 | ... | ... | ... |
| | 16·80 | 15·04 | 13·59 | 12·15 | 11·02 | 9·59 | 8·37 | 7·25 | 6·54 | ... | ... | ... | ... |
| | 17·30 | 15·48 | 14·00 | 12·51 | 11·35 | 9·88 | 8·62 | 7·47 | 6·73 | ... | ... | ... | ... |
| | 17·79 | 15·93 | 14·40 | 12·88 | 11·68 | 10·16 | 8·87 | 7·68 | 6·93 | ... | ... | ... | ... |
| | 18·29 | 16·38 | 14·81 | 13·24 | 12·01 | 10·45 | 9·12 | 7·90 | 7·13 | ... | ... | ... | ... |
| | 18·79 | 16·83 | 15·21 | 13·60 | 12·34 | 10·74 | 9·37 | 8·12 | ... | ... | ... | ... | ... |
| | 19·29 | 17·27 | 15·62 | 13·96 | 12·67 | 11·03 | 9·62 | 8·34 | ... | ... | ... | ... | ... |
| | 19·79 | 17·72 | 16·02 | 14·33 | 13·00 | 11·31 | 9·87 | 8·55 | ... | ... | ... | ... | ... |
| | 20·29 | 18·17 | 16·43 | 14·69 | 13·33 | 11·60 | 10·12 | 8·77 | ... | ... | ... | ... | ... |
| | 20·79 | 18·62 | 16·83 | 15·05 | 13·66 | 11·89 | 10·37 | ... | ... | ... | ... | ... | ... |
| | 21·29 | 19·06 | 17·24 | 15·42 | 13·99 | 12·18 | 10·63 | ... | ... | ... | ... | ... | ... |
| | 21·79 | 19·51 | 17·64 | 15·78 | 14·32 | 12·46 | 10·88 | ... | ... | ... | ... | ... | ... |
| | 22·29 | 19·96 | 18·05 | 16·14 | 14·65 | 12·75 | 11·13 | ... | ... | ... | ... | ... | ... |
| | 22·79 | 20·41 | 18·45 | 16·51 | 14·98 | 13·04 | ... | ... | ... | ... | ... | ... | ... |
| | 23·28 | 20·85 | 18·86 | 16·87 | 15·31 | 13·33 | ... | ... | ... | ... | ... | ... | ... |
| | 23·78 | 21·30 | 19·26 | 17·23 | 15·64 | 13·61 | ... | ... | ... | ... | ... | ... | ... |
| | 24·28 | 21·75 | 19·67 | 17·59 | 15·97 | 13·90 | ... | ... | ... | ... | ... | ... | ... |
| | 24·78 | 22·20 | 20·08 | 17·96 | 16·30 | ... | ... | ... | ... | ... | ... | ... | ... |
| | 25·28 | 22·65 | 20·48 | 18·32 | 16·63 | ... | ... | ... | ... | ... | ... | ... | ... |
| | 25·78 | 23·09 | 20·89 | 18·68 | 16·96 | ... | ... | ... | ... | ... | ... | ... | ... |
| | 26·28 | 23·54 | 21·29 | 19·05 | 17·29 | ... | ... | ... | ... | ... | ... | ... | ... |
| | 26·78 | 23·99 | 21·70 | 19·41 | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| | 27·28 | 24·44 | 22·10 | 19·77 | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| | 27·78 | 24·88 | 22·51 | 20·13 | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| | 28·27 | 25·33 | 22·91 | 20·50 | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| | 0·66 | 0·53 | 0·43 | 0·35 | 0·29 | 0·22 | 0·17 | 0·12 | 0·10 | 0·08 | 0·06 | 0·04 | 0·03 |

number given at bottom of column ; for example—The Weight
12 B. W. G., is 2·78 – 0·29 = 2·49lbs. *f*, full ; *b*, bare.

TABLE 163.—WEIGHT OF SEAMLESS BRASS TUBES 70% OF COPPER AND 30% OF ZINC. Specific gravity 8·558. (The Broughton Copper Company.) IMPERIAL WIRE GAUGE, 1884.

| 1884. | | Thickness of Brass. | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| I. W. G. | | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| Inches. | | 0·212 | 0·192 | 0·176 | 0·160 | 0·144 | 0·128 | 0·116 | 0·104 | 0·092 | 0·080 | 0·072 | 0·064 | 0·056 | 0·048 | 0·040 | 0·036 |
| | | $\frac{7}{32}$ b | $\frac{3}{16}$ f | $\frac{11}{64}$ f | $\frac{5}{32}$ f | $\frac{9}{64}$ f | $\frac{1}{8}$ f | $\frac{7}{64}$ f | $\frac{7}{64}$ b | $\frac{3}{32}$ | $\frac{5}{64}$ f | $\frac{5}{64}$ b | $\frac{1}{16}$ f | $\frac{1}{16}$ b | $\frac{3}{64}$ f | $\frac{3}{64}$ b | $\frac{1}{32}$ f |
| Millimetres. | | 5·385 | 4·877 | 4·470 | 4·064 | 3·658 | 3·251 | 2·946 | 2·642 | 2·337 | 2·032 | 1·829 | 1·626 | 1·422 | 1·219 | 1·016 | 0·914 |
| External Diameter. | | Weight of a Lineal Foot in Pounds. | | | | | | | | | | | | | | | |
| Inches. | Millim. | | | | | | | | | | | | | | | | |
| $\frac{3}{8}$ | 9·5 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 0·21 | 0·18 | 0·16 | 0·14 |
| $\frac{7}{16}$ | 11·1 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 0·28 | 0·25 | 0·22 | 0·18 | 0·17 |
| $\frac{1}{2}$ | 12·7 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 0·36 | 0·32 | 0·29 | 0·25 | 0·21 | 0·19 |
| $\frac{5}{8}$ | 15·9 | ... | ... | ... | ... | ... | ... | ... | ... | ... | 0·51 | 0·46 | 0·42 | 0·37 | 0·32 | 0·27 | 0·25 |
| $\frac{3}{4}$ | 19·0 | ... | ... | ... | ... | ... | ... | ... | ... | 0·70 | 0·62 | 0·57 | 0·51 | 0·45 | 0·39 | 0·33 | 0·30 |
| $\frac{7}{8}$ | 22·2 | ... | ... | ... | ... | ... | ... | ... | 0·93 | 0·84 | 0·74 | 0·67 | 0·60 | 0·53 | 0·46 | 0·39 | 0·35 |
| 1 | 25·4 | ... | ... | ... | ... | ... | ... | 1·19 | 1·08 | 0·97 | 0·86 | 0·78 | 0·70 | 0·62 | 0·53 | 0·45 | 0·40 |
| $1\frac{1}{8}$ | 28·6 | ... | ... | ... | ... | ... | 1·49 | 1·36 | 1·24 | 1·11 | 0·97 | 0·88 | 0·79 | 0·70 | 0·60 | 0·50 | ... |
| $1\frac{1}{4}$ | 31·7 | ... | ... | ... | ... | ... | 1·67 | 1·53 | 1·39 | 1·24 | 1·09 | 0·99 | 0·88 | 0·78 | 0·67 | 0·56 | ... |
| $1\frac{3}{8}$ | 34·9 | ... | ... | ... | ... | 2·06 | 1·86 | 1·70 | 1·54 | 1·37 | 1·21 | 1·09 | 0·98 | 0·86 | 0·74 | 0·62 | ... |
| $1\frac{1}{2}$ | 38·1 | ... | ... | ... | ... | 2·27 | 2·04 | 1·87 | 1·69 | 1·51 | 1·32 | 1·20 | 1·07 | 0·94 | 0·81 | 0·68 | ... |
| $1\frac{5}{8}$ | 41·3 | ... | ... | ... | 2·73 | 2·48 | 2·23 | 2·04 | 1·84 | 1·64 | 1·44 | 1·30 | 1·16 | 1·02 | 0·88 | ... | ... |
| $1\frac{3}{4}$ | 44·4 | ... | ... | ... | 2·96 | 2·69 | 2·42 | 2·21 | 1·99 | 1·78 | 1·56 | 1·41 | 1·26 | 1·10 | 0·95 | ... | ... |
| $1\frac{7}{8}$ | 47·6 | ... | ... | 3·48 | 3·19 | 2·90 | 2·60 | 2·38 | 2·14 | 1·91 | 1·67 | 1·51 | 1·35 | 1·19 | 1·02 | ... | ... |
| 2 | 50·8 | ... | ... | 3·74 | 3·43 | 3·11 | 2·79 | 2·54 | 2·30 | 2·04 | 1·79 | 1·62 | 1·44 | 1·27 | 1·09 | ... | ... |
| $2\frac{1}{8}$ | 54·0 | ... | 4·32 | 3·99 | 3·66 | 3·32 | 2·98 | 2·71 | 2·45 | 2·18 | 1·90 | 1·72 | 1·54 | 1·35 | ... | ... | ... |

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2¼ | 57·1 | ... | 4·60 | 4·25 | 3·89 | 3·53 | 3·16 | 2·88 | 2·60 | 2·31 | 2·02 | 1·83 | 1·63 | 1·43 | ... | ... | ... |
| 2⅜ | 60·3 | 5·34 | 4·88 | 4·51 | 4·13 | 3·74 | 3·35 | 3·05 | 2·75 | 2·45 | 2·14 | 1·93 | 1·72 | 1·51 | ... | ... | ... |
| 2½ | 63·5 | 5·65 | 5·16 | 4·76 | 4·36 | 3·95 | 3·54 | 3·22 | 2·90 | 2·58 | 2·25 | 2·04 | 1·81 | 1·59 | ... | ... | ... |
| 2⅝ | 66·7 | 5·96 | 5·44 | 5·02 | 4·59 | 4·16 | 3·72 | 3·39 | 3·05 | 2·71 | 2·37 | 2·14 | 1·91 | 1·67 | ... | ... | ... |
| 2¾ | 69·8 | 6·27 | 5·72 | 5·28 | 4·83 | 4·37 | 3·91 | 3·56 | 3·20 | 2·85 | 2·49 | 2·24 | 2·00 | 1·76 | ... | ... | ... |
| 2⅞ | 73·0 | 6·57 | 6·00 | 5·53 | 5·06 | 4·58 | 4·09 | 3·73 | 3·36 | 2·98 | 2·60 | 2·35 | 2·09 | 1·84 | ... | ... | ... |
| 3 | 76·2 | 6·88 | 6·28 | 5·79 | 5·29 | 4·79 | 4·28 | 3·90 | 3·51 | 3·11 | 2·72 | 2·45 | 2·19 | 1·92 | ... | ... | ... |
| 3⅛ | 79·3 | 7·19 | 6·56 | 6·04 | 5·52 | 5·00 | 4·47 | 4·06 | 3·66 | 3·25 | 2·84 | 2·56 | 2·28 | ... | ... | ... | ... |
| 3¼ | 82·5 | 7·50 | 6·84 | 6·30 | 5·76 | 5·21 | 4·65 | 4·23 | 3·81 | 3·38 | 2·95 | 2·66 | 2·37 | ... | ... | ... | ... |
| 3⅜ | 85·7 | 7·81 | 7·12 | 6·56 | 5·99 | 5·42 | 4·84 | 4·40 | 3·96 | 3·52 | 3·07 | 2·77 | 2·47 | ... | ... | ... | ... |
| 3½ | 88·9 | 8·12 | 7·40 | 6·81 | 6·22 | 5·63 | 5·03 | 4·57 | 4·11 | 3·65 | 3·19 | 2·87 | 2·56 | ... | ... | ... | ... |
| 3⅝ | 92·0 | 8·43 | 7·68 | 7·07 | 6·46 | 5·84 | 5·21 | 4·74 | 4·26 | 3·78 | 3·30 | 2·98 | 2·65 | ... | ... | ... | ... |
| 3¾ | 95·2 | 8·73 | 7·95 | 7·32 | 6·69 | 6·05 | 5·40 | 4·91 | 4·42 | 3·92 | 3·42 | 3·08 | 2·75 | ... | ... | ... | ... |
| 3⅞ | 98·4 | 9·04 | 8·23 | 7·58 | 6·92 | 6·26 | 5·58 | 5·08 | 4·57 | 4·05 | 3·53 | 3·19 | 2·84 | ... | ... | ... | ... |
| 4 | 101·6 | 9·35 | 8·51 | 7·84 | 7·15 | 6·47 | 5·77 | 5·25 | 4·72 | 4·19 | 3·65 | 3·29 | 2·93 | ... | ... | ... | ... |
| 4¼ | 107·9 | 9·97 | 9·07 | 8·35 | 7·62 | 6·88 | 6·14 | 5·58 | 5·02 | 4·45 | 3·88 | 3·50 | ... | ... | ... | ... | ... |
| 4½ | 114·3 | 10·59 | 9·63 | 8·86 | 8·09 | 7·30 | 6·52 | 5·92 | 5·32 | 4·72 | 4·12 | 3·71 | ... | ... | ... | ... | ... |
| 4¾ | 120·6 | 11·20 | 10·19 | 9·37 | 8·55 | 7·72 | 6·89 | 6·26 | 5·63 | 4·99 | 4·35 | ... | ... | ... | ... | ... | ... |
| 5 | 127·0 | 11·82 | 10·75 | 9·89 | 9·02 | 8·14 | 7·26 | 6·60 | 5·93 | 5·26 | 4·58 | ... | ... | ... | ... | ... | ... |
| 5¼ | 133·3 | 12·44 | 11·31 | 10·40 | 9·48 | 8·56 | 7·63 | 6·93 | 6·23 | 5·53 | ... | ... | ... | ... | ... | ... | ... |
| 5½ | 139·7 | 13·05 | 11·87 | 10·91 | 9·95 | 8·98 | 8·01 | 7·27 | 6·53 | 5·79 | ... | ... | ... | ... | ... | ... | ... |
| 5¾ | 146·0 | 13·67 | 12·43 | 11·42 | 10·41 | 9·40 | 8·38 | 7·61 | 6·84 | ... | ... | ... | ... | ... | ... | ... | ... |
| 6 | 152·4 | 14·29 | 12·99 | 11·94 | 10·88 | 9·82 | 8·75 | 7·95 | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| Per cent. | | 103·4 | 105·2 | 102·1 | 102·9 | 102·6 | 104·4 | 103·3 | 104·6 | 103·1 | 103·6 | 100·0 | 101·5 | 103·5 | 102·0 | 104·8 | 97·3 |

*Note.*—The numbers at bottom show the relative Weights of Brass Tubes made to the B.W.G. and to the I.W.G. 1884, the latter being taken at 100.

The above weights, multiplied by 0·994, give corresponding weights of Brass Tubes 2 and 1 alloy.

.E 164.—WEIGHT OF SEAMLESS BRASS TUBES, CONTAINING 70 % OF COPPER AND 30 % OF ZINC (The Broughton Copper Company). BIRMINGHAM WIRE GAUGE.

| | | Thickness of Brass. | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| B. W. G. | | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| Inches. | | 0·220 | 0·203 | 0·180 | 0·165 | 0·148 | 0·134 | 0·120 | 0·109 | 0·095 | 0·083 | 0·072 | 0·065 | 0·056 | 0·049 | 0·042 | 0·035 |
| | | $\frac{7}{32}$ f | $\frac{13}{64}$ | $\frac{3}{16}$ b | $\frac{11}{64}$ b | $\frac{9}{64}$ f | $\frac{9}{64}$ b | $\frac{1}{8}$ b | $\frac{7}{64}$ | $\frac{3}{32}$ f | $\frac{5}{64}$ f | $\frac{5}{64}$ b | $\frac{1}{16}$ f | $\frac{1}{16}$ b | $\frac{3}{64}$ f | $\frac{3}{64}$ b | $\frac{1}{32}$ f |
| Millimetres. | | 5·59 | 5·16 | 4·57 | 4·19 | 3·76 | 3·40 | 3·05 | 2·77 | 2·41 | 2·11 | 1·83 | 1·65 | 1·47 | 1·24 | 1·07 | 0·89 |
| External Diameter. | | Weight of Lineal Foot in Pounds. | | | | | | | | | | | | | | | |
| Inches. | Millim. | | | | | | | | | | | | | | | | |
| $\frac{3}{8}$ | 9·5 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 0·21 | 0·19 | 0·16 | 0·14 |
| $\frac{7}{16}$ | 11·0 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 0·28 | 0·26 | 0·22 | 0·19 | 0·10 |
| $\frac{1}{2}$ | 12·7 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 0·36 | 0·33 | 0·30 | 0·26 | 0·22 | 0·19 |
| $\frac{5}{8}$ | 15·9 | ... | ... | ... | ... | ... | ... | ... | ... | ... | 0·52 | 0·46 | 0·42 | 0·38 | 0·33 | 0·28 | 0·24 |
| $\frac{3}{4}$ | 19·0 | ... | ... | ... | ... | ... | ... | ... | ... | 0·72 | 0·64 | 0·57 | 0·52 | 0·47 | 0·40 | 0·35 | 0·29 |
| $\frac{7}{8}$ | 22·2 | ... | ... | ... | ... | ... | ... | ... | 0·97 | 0·86 | 0·76 | 0·67 | 0·61 | 0·55 | 0·47 | 0·41 | 0·34 |
| 1 | 25·4 | ... | ... | ... | ... | ... | ... | 1·23 | 1·13 | 1·00 | 0·89 | 0·78 | 0·71 | 0·64 | 0·54 | 0·47 | 0·39 |
| $1\frac{1}{8}$ | 28·6 | ... | ... | ... | ... | ... | 1·55 | 1·40 | 1·29 | 1·14 | 1·01 | 0·88 | 0·80 | 0·72 | 0·61 | 0·53 | ... |
| $1\frac{1}{4}$ | 31·7 | ... | ... | ... | ... | ... | 1·74 | 1·58 | 1·45 | 1·28 | 1·13 | 0·99 | 0·90 | 0·80 | 0·68 | 0·59 | ... |
| $1\frac{3}{8}$ | 34·9 | ... | ... | ... | ... | 2·11 | 1·94 | 1·75 | 1·61 | 1·42 | 1·25 | 1·09 | 0·99 | 0·89 | 0·76 | ... | ... |
| $1\frac{1}{2}$ | 38·1 | ... | ... | ... | ... | 2·33 | 2·13 | 1·93 | 1·77 | 1·55 | 1·37 | 1·20 | 1·09 | 0·97 | 0·83 | ... | ... |
| $1\frac{5}{8}$ | 41·3 | ... | ... | ... | 2·80 | 2·55 | 2·33 | 2·10 | 1·92 | 1·69 | 1·49 | 1·30 | 1·18 | 1·06 | ... | ... | ... |
| $1\frac{3}{4}$ | 44·4 | ... | ... | ... | 3·04 | 2·76 | 2·52 | 2·28 | 2·08 | 1·83 | 1·61 | 1·41 | 1·27 | 1·14 | ... | ... | ... |
| $1\frac{7}{8}$ | 47·6 | ... | ... | 3·55 | 3·29 | 2·98 | 2·72 | 2·45 | 2·24 | 1·97 | 1·73 | 1·51 | 1·37 | 1·23 | ... | ... | ... |
| 2 | 50·8 | ... | ... | 3·81 | 3·53 | 3·19 | 2·91 | 2·63 | 2·40 | 2·11 | 1·85 | 1·62 | 1·46 | 1·31 | ... | ... | ... |

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2⅛ | 54·0 | ... | 4·54 | 4·08 | 3·77 | 3·41 | 3·11 | 2·80 | 2·56 | 2·25 | 1·97 | 1·72 | 1·56 | 1·40 | ... | ... | ... |
| 2¼ | 57·1 | ... | 4·84 | 4·34 | 4·01 | 3·62 | 3·30 | 2·98 | 2·72 | 2·38 | 2·09 | 1·83 | 1·65 | 1·48 | ... | ... | ... |
| 2⅜ | 60·3 | 5·52 | 5·13 | 4·60 | 4·25 | 3·84 | 3·50 | 3·15 | 2·88 | 2·52 | 2·21 | 1·93 | 1·75 | 1·56 | ... | ... | ... |
| 2½ | 63·5 | 5·84 | 5·43 | 4·86 | 4·49 | 4·05 | 3·69 | 3·33 | 3·03 | 2·66 | 2·34 | 2·04 | 1·84 | 1·65 | ... | ... | ... |
| 2⅝ | 66·7 | 6·16 | 5·73 | 5·12 | 4·73 | 4·27 | 3·89 | 3·50 | 3·19 | 2·80 | 2·46 | 2·14 | 1·94 | ... | ... | ... | ... |
| 2¾ | 69·8 | 6·48 | 6·02 | 5·39 | 4·97 | 4·48 | 4·08 | 3·67 | 3·35 | 2·94 | 2·58 | 2·24 | 2·03 | ... | ... | ... | ... |
| 2⅞ | 73·0 | 6·80 | 6·32 | 5·65 | 5·21 | 4·70 | 4·28 | 3·85 | 3·51 | 3·07 | 2·70 | 2·35 | 2·13 | ... | ... | ... | ... |
| 3 | 76·2 | 7·12 | 6·61 | 5·91 | 5·45 | 4·91 | 4·47 | 4·02 | 3·67 | 3·21 | 2·82 | 2·45 | 2·22 | ... | ... | ... | ... |
| 3⅛ | 79·3 | 7·44 | 6·91 | 6·17 | 5·69 | 5·13 | 4·67 | 4·20 | 3·83 | 3·35 | 2·94 | 2·56 | 2·32 | ... | ... | ... | ... |
| 3¼ | 82·5 | 7·76 | 7·20 | 6·43 | 5·93 | 5·35 | 4·86 | 4·37 | 3·99 | 3·49 | 3·06 | 2·66 | 2·41 | ... | ... | ... | ... |
| 3⅜ | 85·7 | 8·08 | 7·50 | 6·70 | 6·17 | 5·56 | 5·06 | 4·55 | 4·15 | 3·63 | 3·18 | 2·77 | 2·50 | ... | ... | ... | ... |
| 3½ | 88·9 | 8·40 | 7·79 | 6·96 | 6·41 | 5·78 | 5·25 | 4·72 | 4·30 | 3·77 | 3·30 | 2·87 | 2·60 | ... | ... | ... | ... |
| 3⅝ | 92·0 | 8·72 | 8·09 | 7·22 | 6·65 | 5·99 | 5·45 | 4·90 | 4·46 | 3·90 | 3·42 | 2·98 | 2·69 | ... | ... | ... | ... |
| 3¾ | 95·2 | 9·04 | 8·38 | 7·48 | 6·89 | 6·21 | 5·64 | 5·07 | 4·62 | 4·04 | 3·54 | 3·08 | 2·79 | ... | ... | ... | ... |
| 3⅞ | 98·4 | 9·36 | 8·68 | 7·74 | 7·13 | 6·42 | 5·84 | 5·25 | 4·78 | 4·18 | 3·66 | 3·19 | 2·88 | ... | ... | ... | ... |
| 4 | 101·6 | 9·68 | 8·98 | 8·01 | 7·37 | 6·64 | 6·03 | 5·42 | 4·94 | 4·32 | 3·79 | 3·29 | 2·98 | ... | ... | ... | ... |
| | | 1·12 | 0·96 | 0·74 | 0·64 | 0·50 | 0·41 | 0·33 | 0·27 | 0·21 | 0·16 | 0·12 | 0·10 | 0·08 | 0·06 | 0·05 | 0·03 |

*Note.*—If the internal diameter is given, add figure at bottom of Column ; for example—The weight per lineal foot of a Brass Tube 2ins. internal diameter, 12 B. W. G. is 2·40 + 0·27 = 2·67lb. *f*, full ; *b*, bare.

| W. G. . | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Percentage | 96·6 | 94·8 | 97·1 | 97·1 | 97·4 | 95·6 | 96·7 | 95·4 | 96·9 | 96·4 | 100·0 | 98·5 | 96·5 | 98·0 | 95·2 | 102·7 |

*Note.*—These numbers show the relative weights of Brass Tubes made to the Imperial Wire Gauge, 1884, and the Birmingham Wire Gauge, the latter being taken at 100.

TABLE 165.—COPPER NAILS AND RIVETS: SIZE AND WEIGHT.

| Description. | Gauge. | Length. | Weight per 1,000. | |
|---|---|---|---|---|
| | No. | Inches. | Lb. | Oz. |
| Copper nails, wrought, clench, flat-head, full countersunk | 13 | 1 | 2 | 9 |
| | 13 | $1\frac{1}{8}$ | 2 | 15 |
| ,, | 12 | $1\frac{1}{4}$ | 4 | 8 |
| ,, | 11 | $1\frac{1}{2}$ | 6 | 6 |
| ,, | 13 | $1\frac{3}{4}$ | 4 | 12 |
| ,, | 11 | $1\frac{3}{4}$ | 7 | 8 |
| ,, | 11 | 2 | 8 | 8 |
| ,, | 10 | $2\frac{1}{4}$ | 12 | 12 |
| ,, | 11 | $2\frac{3}{8}$ | 10 | 0 |
| ,, | 11 | $2\frac{1}{2}$ | 10 | 10 |
| ,, | 9 | $2\frac{1}{2}$ | 17 | 12 |
| ,, | 9 | $2\frac{3}{4}$ | 19 | 4 |
| ,, | 8 | 3 | 25 | 8 |
| ,, | 8 | $3\frac{1}{4}$ | 28 | 0 |
| ,, | 8 | $3\frac{1}{2}$ | 29 | 12 |
| ,, | 7 | $3\frac{3}{4}$ | 36 | 0 |
| ,, | 6 | 4 | 48 | 8 |
| ,, | 6 | $4\frac{1}{2}$ | 55 | 4 |
| ,, | 4 | 5 | 82 | 12 |
| ,, | 3 | $5\frac{1}{2}$ | 108 | 0 |
| ,, | 3 | 6 | 119 | 0 |
| ,, | 4 | 6 | 107 | 12 |
| ,, | 3 | 7 | 136 | 12 |
| ,, | 3 | $7\frac{1}{2}$ | 146 | 4 |
| ,, | 2 | 8 | 189 | 0 |
| ,, | 2 | $8\frac{1}{2}$ | 199 | 0 |
| Spike die-heads, with flat points | 12 | $1\frac{1}{2}$ | 4 | 12 |
| ,, ,, | 10 | $1\frac{3}{4}$ | 9 | 8 |
| ,, ,, | 9 | 2 | 12 | 0 |
| ,, ,, | 7 | $2\frac{1}{2}$ | 19 | 10 |
| ,, ,, | 6 | 3 | 30 | 0 |
| ,, ,, | 4 | $3\frac{1}{2}$ | 48 | 0 |
| ,, ,, | 2 | $4\frac{1}{2}$ | 84 | 8 |
| Rose-heads, with flat points | 14 | $\frac{3}{4}$ | 1 | 9 |
| ,, ,, | 13 | 1 | 2 | 4 |
| ,, ,, | 13 | $1\frac{1}{4}$ | 3 | 0 |
| ,, ,, | 12 | $1\frac{1}{2}$ | 4 | 6 |
| ,, ,, | 10 | $1\frac{3}{4}$ | 9 | 8 |
| ,, ,, | 10 | 2 | 10 | 12 |

TABLE 165.—COPPER NAILS AND RIVETS (*continued*).

| Description. | Gauge. | Length. | Weight per 1,000. | |
|---|---|---|---|---|
| | No. | Inches. | Lb. | Oz. |
| Rose-heads, with flat points | 8 | $2\frac{1}{4}$ | 16 | 14 |
| " " | 8 | $2\frac{1}{2}$ | 19 | 8 |
| " " | 6 | 3 | 30 | 0 |
| " " | 5 | $3\frac{1}{2}$ | 42 | 8 |
| " " | 4 | 4 | 53 | 12 |
| " " | 3 | $4\frac{1}{2}$ | 71 | 0 |
| " " | 2 | 5 | 93 | 0 |
| Clasp | ... | $2\frac{1}{2}$ | 13 | 0 |
| " | ... | 2 | 9 | 0 |
| " | ... | $1\frac{1}{2}$ | 4 | 0 |
| " | ... | $1\frac{1}{4}$ | 2 | 10 |
| " | ... | 1 | 1 | 12 |
| " | ... | $1\frac{1}{2}$ | ... | |
| Cut copper nails, brads, billed | ... | $\frac{5}{8}$ | 0 | 10 |
| " " | ... | $\frac{3}{4}$ | 0 | 12 |
| " " | ... | 1 | 1 | 10 |
| " " | ... | $1\frac{1}{4}$ | 2 | 4 |
| " " | ... | $1\frac{1}{2}$ | 3 | 12 |
| " " | ... | $1\frac{3}{4}$ | 5 | 8 |
| Lightning conductor, countersunk heads, and flat points, jagged | 6 | $1\frac{1}{2}$ | 10 | 8 |
| | 5 | $1\frac{3}{4}$ | 15 | 0 |
| " | 4 | 2 | 18 | 8 |
| " | 3 | $2\frac{1}{4}$ | 26 | 0 |
| " | 1 | $2\frac{1}{2}$ | 40 | 0 |
| " | 1 | 3 | 52 | 0 |
| Scarf tacks, square flat-heads, with sharp points | 16 | $\frac{1}{2}$ | 0 | 9 |
| | 16 | ... | 0 | 11 |
| " | 16 | $\frac{3}{4}$ | 1 | 1 |
| " | 15 | $\frac{7}{8}$ | 1 | 6 |
| Slating | ... | $1\frac{1}{2}$ | ... | |
| Coppersmith's rivets, flat pan-head. | 2 | $\frac{7}{8}$ | 22 | 4 |
| " " | 4 | $\frac{5}{8}$ | 13 | 12 |
| " " | 6 | $\frac{5}{8}$ | 9 | 12 |
| " " | 7 | $\frac{1}{2}$ | 6 | 14 |
| " " | 10 | $\frac{3}{8}$ | 3 | 0 |
| " " | 11 | $\frac{5}{16}$ | 2 | 4 |
| " " | 12 | $\frac{1}{4}$ | 1 | 4 |
| | Inches. | | | |
| " snap-heads | $\frac{1}{2}$ | $1\frac{1}{4}$ | 118 | 0 |
| " " | $\frac{7}{16}$ | $1\frac{1}{4}$ | 91 | 0 |
| " " | $\frac{7}{16}$ | 1 | 78 | 0 |
| " " | $\frac{1}{2}$ | 1 | 102 | 0 |
| " " | $\frac{3}{8}$ | $\frac{7}{8}$ | 55 | 0 |
| " " | $\frac{3}{8}$ | $1\frac{1}{4}$ | 71 | |

TABLE 165.—COPPER NAILS AND RIVETS (*continued*).

| Description. | Gauge. | Length. | Weight per 1,000. |
|---|---|---|---|
| | No. | Inches. | Lb. Oz. |
| Coppersmith's rivets, tinned for hoses— | | | |
| ,, hose No. 1 . | 8 | $\frac{3}{8}$ | 4 8 |
| ,, hose No. 2 . | 7 | $\frac{7}{16}$ | 5 12 |
| ,, hose No. 3 . | 7 | 8 | 6 8 |
| ,, hose No. 4 . | 7 | 9 | 7 4 |
| ,, hose No. 4 . | 7 | 11 | 8 4 |
| ,, washers for do.— | | | |
| ,, hose No. 1 . | ... | ... | 2 4 |
| ,, hose No. 2 . | ... | ... | 2 12 |
| ,, hose No. 3 . | ... | ... | 2 12 |
| ,, hose No. 4 . | ... | ... | 3 4 |

Brazed Copper tubes weigh more per lineal foot than seamless tubes. An exact general multiple cannot be given, as the proportion of difference varies with the thickness, the diameter, and the kind of brazed joint.

Mandrel-drawn brazed Copper tubes weigh the same as Seamless tubes.

TABLE 166.—SHEET LEAD: WEIGHT PER SQUARE FOOT.
Usual size of Sheets, 32 feet × 7 feet.

| Weight per Square Foot. | Thickness. | Weight per Square Foot. | Thickness. |
|---|---|---|---|
| Pounds. | Inch. | Pounds. | Inch. |
| $2\frac{1}{2}$ | ·042 or $\frac{1}{24}$ | $5\frac{1}{2}$ | ·093 or $\frac{1}{11}$ full |
| 3 | ·051 or $\frac{1}{20}$ full | 6 | ·101 or $\frac{1}{10}$ |
| $3\frac{1}{2}$ | ·059 | $6\frac{1}{2}$ | ·110 or $\frac{1}{9}$ |
| 4 | ·067 or $\frac{1}{15}$ full | 7 | ·118 or $\frac{2}{17}$ |
| $4\frac{1}{2}$ | ·076 or $\frac{1}{13}$ | $7\frac{1}{2}$ | ·126 or $\frac{1}{8}$ bare |
| 5 | ·084 or $\frac{1}{12}$ full | 8 | ·135 or $\frac{2}{15}$ full |

TABLE 167.—SHEET LEAD. FRENCH PRACTICE.
Usual size of sheets, 2·80 metres and 3·88 metres wide, 8 to 10 metres long (9 feet 2 inches and 12 feet 9 inches wide, 26 feet to 33 feet long).

| Thickness. | Weight per Square Metre. | Thickness. | Weight per Square Metre. |
|---|---|---|---|
| Millimetres. | Kilogrs. or Lbs. | Millimetres. | Kilogrs. or Lbs. |
| 1 | 11·25 or 24·8 | 3 | 34·00 or 75·0 |
| [illegible] | 17·00 or 37·5 | 4 | 45·40 or 100·1 |
| | 22·70 or 50·1 | 5 | 56·80 or 125·2 |
| | 28·40 or 62·6 | 7 | 79·50 or 175·3 |

TABLE 168.—SOLID DR... ...ONS AND WEIGHTS

W...

(Walkers, Park...

| Bore. | Length. | Weights of One Length fo... |
|---|---|---|
| Inches. | Feet. | Pounds. |
| $\frac{3}{16}$ | 15 | 15 |
| $\frac{1}{4}$ | 15 | 10, 15, 20 |
| $\frac{3}{8}$ | 15 | 10, 15, 20, 25 |
| $\frac{1}{2}$ | 15 | 14, 15, 16, 18, 20, 22, 25, 27, 30, 35 |
| $\frac{9}{16}$ | 15 | 16, 18, 20, 22 |
| $\frac{5}{8}$ | 15 | 17, 21, 25, 30, 35, 40, 45 |
| $\frac{3}{4}$ | 15 | 22, 24, 26, 28, 32, 36, 40, 45, 50, 55 |
| $\frac{7}{8}$ | 15 | 28, 36 |
| 1 | 15 | 30, 36, 42, 45, 48, 52, 56, 60, 64, 70 |
| $1\frac{1}{8}$ | 15 | 42, 52, 60, 68, 76 |
| $1\frac{1}{4}$ | 12 | 28, 36, 42, 48, 52, 60, 64 |
| $1\frac{1}{2}$ | 12 | 28, 36, 48, 56, 60, 72, 84, 96 |
| $1\frac{3}{4}$ | 12 | 60, 72, 84, 96 |
| 2 | 12 | 36, 56, 72, 84, 96, 112, 120 |
| $2\frac{1}{4}$ | 12 | 100, 132 |
| $2\frac{1}{2}$ | 10 | 60, 70, 84, 96, 112, 120 |
| $2\frac{3}{4}$ | 10 | 100 |
| 3 | 10 | 100, 112, 120, 130, 140, 150 |
| $3\frac{1}{2}$ | 10 | 112, 130, 150, 160, 180 |
| 4 | 10 | 140, 160, 170, 200, 220 |
| $4\frac{1}{2}$ | 10 | 140, 170, 220 |
| 5 | 10 | 150, 220, 250 |
| $5\frac{1}{2}$ | 10 | 220 |
| 6 | 10 | 220 |

DRAWN SOIL PIPE.

| | | |
|---|---|---|
| $2\frac{1}{2}$ | 10 | 36, 45, 60, 70 |
| 3 | 10 | 45, 53, 60, 68, 74, 80 |
| $3\frac{1}{2}$ | 10 | 52, 60, 70, 90 |
| 4 | 10 | 56, 60, 70, 80, 100, 112 |
| $4\frac{1}{2}$ | 10 | 70, 80, 90, 100, 112 |
| 5 | 10 | 75, 88, 100, 112 |
| $5\frac{1}{2}$ | 10 | 90, 106 |
| 6 | 10 | 90, 106 |

TABLE 165.—COPPER AND DRAWN LEAD PIPES (*continued*).

**DRAWN SQUARE SOIL PIPE.**

| Bore. | Length. | Weights of One Length for Various Thicknesses |
|---|---|---|
| Inches. | Feet. | Pounds. |
| $3\frac{1}{2}\times3\frac{1}{2}$ | 10 | 60, 80 |
| $4\times3$ | 10 | 80, 100 |

**COMPOSITION PIPE (Lead and Tin).**

| | | |
|---|---|---|
| Diameters, inches . | $\frac{1}{8}$, $\frac{3}{16}$, $\frac{1}{4}$, $\frac{5}{16}$, $\frac{3}{8}$, $\frac{7}{16}$, | About $\frac{1}{2}$ cwt. each coil. |
| Average length of coils, feet . . | 670, 240, 220, 170, 150, 120, | |
| Diameters, inches . | $\frac{1}{2}$, $\frac{9}{16}$, $\frac{5}{8}$, $\frac{3}{4}$, $\frac{7}{8}$, 1, $1\frac{1}{4}$ | |
| Average length of coils, feet . . | 100, 90, 70, 70, 60, 50, 40 | |

TABLE 169.—TIN PLATES: DIMENSIONS AND WEIGHTS.

| Description. | Mark. | Dimensions of Sheets. | Number of Sheets in a Box. | Weight of each Box. |
|---|---|---|---|---|
| | | Inches. | Sheets. | Pounds. |
| Common No. 1 . . | IC | 14×10 | 225 | 108 |
| Cross No. 1 . . . | IX | 14×10 | 225 | 136 |
| Two crosses No. 1 . . | IXX | 14×10 | 225 | 157 |
| Three crosses No. 1 . . | IXXX | 14×10 | 225 | 178 |
| Four crosses No. 1 . . | IXXXX | 14×10 | 225 | 199 |
| Common No. 1 . . . | IC | 14×20 | 112 | 108 |
| Cross No. 1 . . . | IX | 14×20 | 112 | 136 |
| Two crosses No. 1 . . | IXX | 14×20 | 112 | 157 |
| Three crosses No. 1 . | IXXX | 14×20 | 112 | 178 |
| Four crosses No. 1 . . | IXXXX | 14×20 | 112 | 199 |
| Common No. 1 . . | IC | 28×20 | 56 | 108 |
| Cross No. 1 . . . | IX | 28×20 | 56 | 136 |
| Two crosses No. 1 . . | IXX | 28×20 | 56 | 157 |
| Three crosses No. 1 . . | IXXX | 28×20 | 56 | 178 |
| Four crosses No. 1 . . | IXXXX | 28×20 | 56 | 199 |
| Common No. 1 . . . | IC | 12×12 | 225 | 108 |
| Cross No. 1 . . . | IX | 12×12 | 225 | 136 |
| Two crosses No. 1 . . | IXX | 12×12 | 225 | 157 |
| Three crosses No. 1 . | IXXX | 12×12 | 225 | 178 |

TABLE 169.—TIN PLATES: DIMENSIONS AND WEIGHTS (*continued*).

| Description. | Mark. | Dimensions of Sheets. | Number of Sheets in a Box. | Weight of each Box. |
|---|---|---|---|---|
| | | Inches. | Sheets. | Pounds. |
| Four crosses No. 1 . . | IXXXX | 12×12 | 225 | 199 |
| Common doubles . . | DC | 17×12½ | 100 | 94 |
| Cross doubles . . . | DX | 17×12½ | 100 | 122 |
| Two cross doubles . . | DXX | 17×12½ | 100 | 143 |
| Three cross doubles . . | DXXX | 17×12½ | 100 | 164 |
| Four cross doubles . | DXXXX | 17×12½ | 100 | 185 |
| Common doubles . . | DC | 17×25 | 50 | 94 |
| Cross doubles . . | DX | 17×25 | 50 | 122 |
| Two cross doubles . . | DXX | 17×25 | 50 | 143 |
| Three cross doubles . | DXXX | 17×25 | 50 | 164 |
| Four cross doubles . . | DXXXX | 17×25 | 50 | 185 |
| Common doubles . . | DC | 34×25 | 25 | 94 |
| Cross doubles . . . | DX | 34×25 | 25 | 122 |
| Two cross doubles . . | DXX | 34×25 | 25 | 143 |
| Three cross doubles . . | DXXX | 34×25 | 25 | 164 |
| Four cross doubles . | DXXXX | 34×25 | 25 | 185 |
| Small common doubles . | SDC | 15×11 | 200 | 167 |
| Small cross doubles . . | SDX | 15×11 | 200 | 188 |
| Small two cross doubles. | SDXX | 15×11 | 200 | 209 |
| Small three cross doubles | SDXXX | 15×11 | 200 | 230 |
| Small four cross doubles | SDXXXX | 15×11 | 200 | 251 |
| Small common doubles . | SDC | 15×22 | 100 | 167 |
| Small cross doubles . . | SDX | 15×22 | 100 | 188 |
| Small two cross doubles. | SDXX | 15×22 | 100 | 209 |
| Small three cross doubles | SDXXX | 15×22 | 100 | 230 |
| Small four cross doubles | SDXXXX | 15×22 | 100 | 251 |

*Note.*—The weights of the cross-marked boxes advance at the rate of 21 pounds per Cross.

TABLE 170.—BLOCK TIN PIPES: WEIGHT PER YARD.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Bore . . . | $\frac{1}{4}$, | $\frac{5}{16}$, | $\frac{3}{8}$, | $\frac{7}{16}$, | $\frac{1}{2}$, | $\frac{5}{8}$, | $\frac{3}{4}$, | $\frac{7}{8}$, | 1 | inch. |
| Weight . . . | 7, | 9, | 11, | 14, | 17, | 23, | 30, | 38, | 48 | ounces. |

## TABLE 171.—ZINC SHEETS: ACCORDING TO THE V.M. ZINC GAUGE.

(Vielle-Montagne Company.)

| V. M. Gauge. | Approximate Thickness. | | Approximate Weight per Square Foot. | | | 36 in. × 72 in. | | | | 36 in. × 84 in. | | | | 36 in. × 96 in. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Approximate Weight of Sheets. | | | Sheets per 500 Kilos, or 1102½ Lbs. English. | Approximate Weight of Sheets. | | | Sheets per 500 Kilos, or 1102½ Lbs. English. | Approximate Weight of Sheets. | | | Sheets per 500 Kilos, or 1102½ Lbs. English. |
| | Thousandths of an Inch. | Metric Equivalent in Thousandths of a Millimetre. | Pounds. | Ounces. | Drachms. | Pounds. | Ounces. | Drachms. | about | Pounds. | Ounces. | Drachms. | about | Pounds. | Ounces. | Drachms. | about |
| 1 | 0·004 | 0.100 | ... | 2 | 5 | Nos. 1 and 2 are only rolled to order and special dimensions. | | | | | | | | | | | |
| 2 | ·006 | ·141 | ... | 3 | 4 | | | | | | | | | | | | |
| 3 | ·007 | ·171 | ... | 3 | 15 | 4 | 6 | 14 | 249 | 5 | 2 | 11 | 213 | 5 | 14 | 8 | 187 |
| 4 | ·008 | ·209 | ... | 4 | 13 | 5 | 6 | 10 | 204 | 6 | 5 | 1 | 175 | 7 | 3 | 8 | 153 |
| 5 | ·010 | ·247 | ... | 5 | 11 | 6 | 6 | 6 | 172 | 7 | 7 | 7 | 147 | 8 | 8 | 8 | 129 |
| 6 | ·011 | ·291 | ... | 6 | 11 | 7 | 8 | 6 | 146 | 8 | 12 | 7 | 126 | 10 | ... | 8 | 110 |
| 7 | ·013 | ·337 | ... | 7 | 12 | 8 | 11 | 8 | 126 | 10 | 2 | 12 | 108 | 11 | 10 | ... | 95 |
| 8 | ·015 | ·386 | ... | 8 | 14 | 9 | 15 | 12 | 110 | 11 | 10 | 6 | 95 | 13 | 5 | ... | 83 |
| 9 | ·018 | ·450 | ... | 10 | 5 | 11 | 9 | 10 | 95 | 13 | 8 | 9 | 81 | 15 | 7 | 8 | 71 |
| 10 | ·020 | ·500 | ... | 11 | 7 | 12 | 13 | 14 | 86 | 15 | ... | 3 | 73 | 17 | 2 | 8 | 64 |
| 11 | ·023 | ·580 | ... | 13 | 5 | 14 | 15 | 10 | 74 | 17 | 7 | 9 | 63 | 19 | 15 | 8 | 55 |
| 12 | ·026 | ·660 | ... | 15 | 2 | 17 | 0 | 4 | 65 | 19 | 13 | 10 | 56 | 22 | 11 | ... | 49 |
| 13 | ·029 | ·740 | 1 | ... | 15 | 19 | 0 | 14 | 57 | 22 | 3 | 11 | 50 | 25 | 6 | 8 | 43 |
| 14 | ·032 | ·820 | 1 | 2 | 12 | 21 | 1 | 8 | 52 | 24 | 9 | 12 | 45 | 28 | 2 | ... | 39 |
| 15 | ·038 | ·950 | 1 | 5 | 12 | 24 | 7 | 8 | 45 | 28 | 8 | 12 | 39 | 32 | 10 | ... | 34 |
| 16 | ·043 | 1·080 | 1 | 8 | 12 | 27 | 13 | 8 | 39 | 32 | 7 | 12 | 34 | 37 | 2 | ... | 30 |
| 17 | ·048 | 1·210 | 1 | 11 | 11 | 31 | 2 | 6 | 35 | 36 | 5 | 7 | 30 | 41 | 8 | 8 | 27 |
| 18 | ·053 | 1·340 | 1 | 14 | 11 | 34 | 8 | 6 | 31 | 40 | 4 | 7 | 27 | 46 | ... | 8 | 24 |
| 19 | ·058 | 1·470 | 2 | 1 | 11 | 37 | 14 | 6 | 29 | 44 | 3 | 7 | 25 | 50 | 6 | 8 | 22 |
| 20 | ·063 | 1·600 | 2 | 4 | 10 | 41 | 3 | 4 | 27 | 48 | 1 | 2 | 23 | 54 | 15 | ... | 20 |
| 21 | ·070 | 1·780 | 2 | 8 | 12 | 45 | 13 | 8 | 24 | 53 | 7 | 12 | 21 | 61 | 2 | ... | 18 |
| 22 | ·077 | 1·960 | 2 | 12 | 14 | 50 | 7 | 12 | 22 | 58 | 14 | 6 | 19 | 67 | 5 | ... | 16 |
| 23 | ·084 | 2·140 | 3 | 1 | 1 | 55 | 3 | 2 | 20 | 64 | 6 | 5 | 17 | 73 | 9 | 8 | 15 |
| 24 | ·091 | 2·320 | 3 | 5 | 3 | 59 | 13 | 6 | 18 | 69 | 12 | 15 | 16 | 79 | 12 | 8 | 14 |
| 25 | ·098 | 2·500 | 3 | 9 | 5 | 64 | 7 | 10 | 17 | 75 | 3 | 9 | 15 | 85 | 15 | 8 | 13 |
| 26 | ·105 | 2·680 | 3 | 13 | 7 | 69 | 1 | 14 | 16 | 80 | 10 | 3 | 14 | 92 | 2 | 8 | 12 |

## TABLE 172.—ZINC SHEETS: ACCORDING TO THE ENGLISH ZINC GAUGE.

(London Zinc Mills.)

| Gauge No. | Approximate Weight per Square Foot. | Thousandths of an Inch. | 7 ft. × 2 ft. 8 in. Approximate Weight per Sheet. | 7 ft. × 2 ft. 8 in. Approximate Number of Sheets in 10 Cwt. | 7 ft. × 3 ft. Approximate Weight per Sheet. | 7 ft. × 3 ft. Approximate Number of Sheets in 10 Cwt. | 8 ft. × 3 ft. Approximate Weight per Sheet. | 8 ft. × 3 ft. Approximate Number of Sheets in 10 Cwt. | Nearest Birmingham Wire Gauge. |
|---|---|---|---|---|---|---|---|---|---|
| | Oz. | | Lbs. Oz. | | Lbs. Oz. | | Lbs. Oz. | | |
| 1 | 2¼ | ·004 | 2 10 | 427 | ... | ... | ... | ... | 41 |
| 2 | 3¼ | ·006 | 3 13 | 294 | ... | ... | ... | ... | 38 |
| 3 | 3¾ | ·007 | ... | ... | 4 15 | 227 | ... | ... | 37 |
| 4 | 4¾ | ·008 | ... | ... | 6 4 | 180 | ... | ... | 34 |
| 5 | 5¼ | ·010 | ... | ... | 7 9 | 148 | ... | ... | 31 |
| 6 | 6¾ | ·011 | 7 14 | 142 | 8 14 | 126 | 10 2 | 111 | 30 |
| 7 | 7¾ | ·013 | 9 1 | 124 | 10 3 | 110 | 11 10 | 96 | 29 |
| 8 | 9 | ·015 | 10 8 | 107 | 11 13 | 95 | 13 8 | 83 | 28 |
| 9 | 10 | ·017 | 11 11 | 96 | 13 2 | 85 | 15 0 | 75 | 27 |
| 10 | 11½ | ·019 | 13 7 | 83 | 15 2 | 74 | 17 4 | 65 | 25 |
| 11 | 13 | ·021 | 15 3 | 74 | 17 1 | 66 | 19 8 | 57 | 24 |
| 12 | 15 | ·025 | 17 8 | 64 | 19 11 | 57 | 22 8 | 50 | 23 |
| 13 | 17 | ·028 | ... | ... | 22 5 | 50 | 25 8 | 44 | 22 |
| 14 | 19 | ·031 | ... | ... | 24 15 | 45 | 28 8 | 39 | 21 |
| 15 | 22 | ·036 | ... | ... | 28 14 | 39 | 33 0 | 34 | 20 |
| 16 | 25 | ·041 | ... | ... | 32 13 | 34 | 37 8 | 30 | 19 |
| 17 | 28 | ·046 | ... | ... | 36 12 | 30 | 42 0 | 27 | 18 |
| 18 | 31 | ·051 | ... | ... | 40 11 | 28 | 46 8 | 24 | ... |
| 19 | 35 | ·059 | ... | ... | 45 15 | 24 | 52 8 | 21 | 17 |
| 20 | 39 | ·065 | ... | ... | 51 3 | 22 | 58 8 | 19 | 16 |
| 21 | 43 | ·072 | ... | ... | 56 7 | 20 | 64 8 | 17 | 15 |

Sheets thicker than above are rolled to Birmingham Wire Gauge.

WIRE ROPES. *See* STRENGTH OF MATERIALS (pp. 386—400).

CHAINS AND CHAIN CABLES. *See* STRENGTH OF MATERIALS (pp. 400—408).

# STRENGTH OF MATERIALS.

## Strength of Beams.

The ultimate transverse strength of a cantilever or homogeneous beam of uniform square or rectangular section, fixed at one end and loaded at the other end, is usually expressed by the formula.—

$$W = \frac{bd^2s}{6l} \quad \text{or} \quad \frac{\cdot 16667bd^2s}{l}$$

W = breaking weight at the end of the beam.
$b$ = breadth of the beam in inches.
$d$ = depth of the beam in inches.
$l$ = length of the beam, between the fixed point and the load, in inches; or the distance apart of two supports.
$s$ = ultimate tensile strength of the beam per square inch.

This formula, it is known, is materially defective, in understating the actual strength.

The correct formula is :—

1. *Beam fixed at one end, loaded at the other end.*

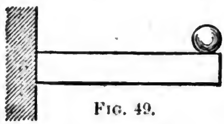


Fig. 49.

$$W = \frac{bd^2s}{3\cdot 43l}, \quad \text{or} \quad \frac{\cdot 292bd^2s}{l} \quad . \quad . \quad . \quad . \quad . \quad (1)$$

$$s = \frac{3\cdot 43Wl}{bd^2}, \quad \text{or} \quad \frac{Wl}{\cdot 292bd^2} \quad . \quad . \quad . \quad . \quad . \quad (2)$$

A beam freely supported at both ends, and loaded at the middle, bears four times the breaking weight of the cantilever :—

2. *Beam supported at both ends, loaded at the middle.*

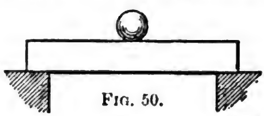


Fig. 50.

$$W = \frac{1\cdot 167bd^2s}{l} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

$$s = \frac{Wl}{1 \cdot 167bd^2} \qquad (4)$$

A beam fixed at each end, and loaded at the middle, bears eight times the breaking weight of the cantilever :—

3. *Beam fixed at each end, loaded at the middle.*

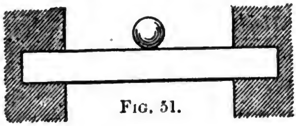


FIG. 51.

$$W = \frac{2 \cdot 333bd^2s}{l} \qquad (5)$$

$$s = \frac{Wl}{2 \cdot 333bd^2} \qquad (6)$$

Beams on which the load is equally distributed, are capable of a breaking weight double the central load given in the foregoing formulæ :—

4. *Beam fixed at one end, and uniformly loaded.*

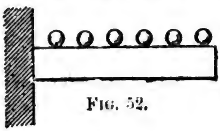


FIG. 52.

$$W = \frac{\cdot 583bd^2s}{l} \qquad (7)$$

$$s = \frac{Wl}{\cdot 583bd^2} \qquad (8)$$

5. *Beam supported at both ends, uniformly loaded.*

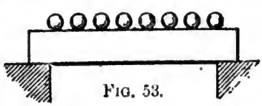


FIG. 53.

$$W = \frac{2 \cdot 333bd^2s}{l} \qquad (9)$$

$$s = \frac{Wl}{2 \cdot 333bd^2} \qquad (10)$$

6. *Beam fixed at each end, uniformly loaded.*

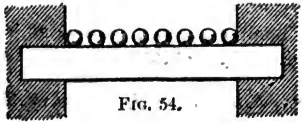


FIG. 54.

$$W = \frac{4 \cdot 667 bd^2 s}{l} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (11)$$

$$s = \frac{Wl}{4 \cdot 667 bd^2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (12)$$

When a concentrated load is applied elsewhere than at the middle of a beam, the breaking weight is inversely proportional to the product $mn$ of the segments $m$ and $n$ into which the beam is divided by the load. The product when the load is at the centre is $(\frac{1}{2} l)^2$, and the formula (3), for a beam supported at both ends, becomes—

7. *Beam supported at both ends and loaded at a point between the middle and one end.*

$$W = \frac{1 \cdot 167 bd^2 ls}{mn} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (13)$$

In like manner—

8. *Beam fixed at each end, and loaded at a point between the middle and one end.*

$$W = \frac{2 \cdot 333 bd^2 ls}{mn} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (14)$$

The breaking weight of a homogeneous beam of uniform square section, of which one diagonal is vertical, supported at both ends, is expressed by the formula—

9. *Square beam supported at both ends, loaded at the centre; one of the diagonals vertical.*

$$W = \frac{\cdot 943 b^3 s}{l} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (15)$$

showing that the diagonally placed square beam has only about 81 per cent. of the strength of the square set beam, formula (3).

The breaking weight of a homogeneous uniform cylindrical beam, supported at both ends, is given by the formula—

10. *Cylindrical beam supported at both ends, loaded at the centre.*

$$W = \frac{\cdot 726 d^3 s}{l} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (16)$$

It is deducible that the transverse strength of a cylindrical beam is only 90 per cent. of that of a square beam, laid square, of the same sectional area.

The breaking weight of a homogeneous uniform beam of elliptical section, laid with either axis vertical, is as follows :—

11. *Beam of elliptical section, supported at both ends, laid with one axis vertical.*

$$W = \frac{\cdot 726 b d^2 s}{l} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (17)$$

in which $b$ is the length of the horizontal axis, and $d$ is that of the vertical axis.

The strength of equal flanged or hollow beams may be calculated by the formula :—

*Symmetrical flanged or hollow beam. General formula.*

$$W = \frac{d'' s (4a + 1 \cdot 167 a'')}{l} \quad . \quad . \quad . \quad . \quad . \quad (18)$$

$a$ = the sectional area of one flange, in square inches.
$a''$ = the area of the vertical web, or webs, in square inches, the reputed vertical height of the web being taken, for calculation, equal to the depth of the beam minus the thickness of one flange.
$d''$ = the reputed depth, equal to that of the web.
$s$ = the ultimate tensile strength in tons per square inch.
$l$ = the span in inches.
W = the breaking load in tons at the centre.

For the strength of cast-iron flange beams, the following formula is applicable in which the tensile strength is taken as 7 tons per square inch :—

*Ultimate transverse strength of cast-iron beams.*

$$W = \frac{d''(7a + 2a'')}{3l} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (19)$$

W = breaking weight in tons at the middle.
$a$ = sectional area of the lower flange, square inches.
$a''$ = sectional area of the web, taken at the reputed depth (total depth minus thickness of lower flange), square inches.
$l$ = span in feet.

For various tensile strengths per square inch, the following are the constants to be employed in the formula :—

| Tons per Square Inch. | Constants in formula (19) for $a$ | for $a''$. |
|---|---|---|
| 6 | 6 | 1·7 |
| $6\frac{3}{4}$ | $6\frac{3}{4}$ | 1·9 |
| 7 | 7 | 2·0 |
| $7\frac{1}{2}$ | $7\frac{1}{2}$ | 2·2 |
| 8 | 8 | 2·3 |
| 9 | 9 | 2·6 |
| 10 | 10 | 2·9 |

*Ultimate transverse strength of solid rolled joists, of wrought iron (approximate).*

$$W = \frac{7d(a + \frac{1}{4}a'')}{l} \qquad (20)$$

*Note.*—The sectional area of the web ($a''$) is, in this case, taken for the whole depth of the joist.

2. The ultimate tensile strength of the metal is taken at 20 tons per square inch.

3. For iron or steel of other than 20 tons tensile strength per square inch, substitute ⅓rd of the other tensile strength, for the constant 7 in the formula.

*Ultimate transverse strength of riveted wrought-iron girders (approximate).*

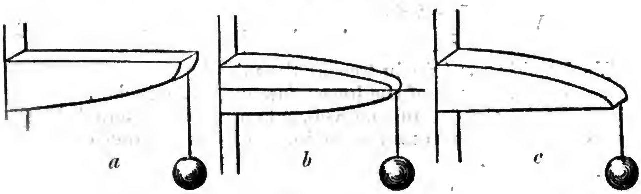
$$W = \frac{4\frac{2}{3}d(a' + \frac{1}{4}a'')}{l} \qquad (21)$$

**Cantilevers and Beams of Uniform Strength.**

The basic forms, exclusive of provision for shearing resistance, are as follows :—

1. *Cantilevers of uniform transverse strength, loaded at one end.*

1. When a cantilever is rectangular in section, it may be of either of the parabolic forms *a*, *b*, *c*, figs. 55—57.




Figs. 55—57.

2. When the section, fig. 58, is rectangular and the depth is constant, the breadth is in proportion to the distance from the end of the beam, and the beam is triangular in plan.

3. When the section is double-flanged, as in fig. 59, or hollow-rectangular, and the breadth uniform, the form of the beam, in side elevation, is triangular, supposing that the resistance of the web is not calculated.

4. A double-flanged semi-beam, fig. 60, or hollow beam rect-

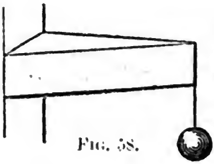


FIG. 58.

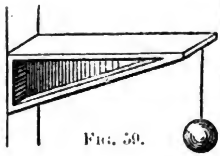


FIG. 59.

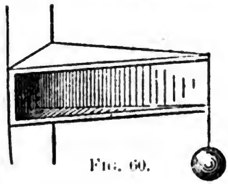


FIG. 60.

angular in section, of uniform depth, is triangular in plan, when calculated for the flanges only.

5. When the section of the semi-beam is circular, the outline is formed by the revolution of a cubic parabola on its axis, fig. 61.

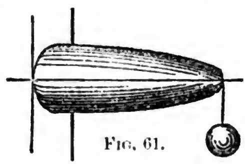


FIG. 61.

6. When the section of the semi-beam is annular, the form is generated by the revolution of a parabola on its axis. If the thickness varies with the diameter, the semi-beam is cubic-parabolic.

2. *Cantilevers of uniform strength, uniformly loaded.*

1. Rectangular in section, breadth uniform, triangular in side elevation, fig. 62.

2. Rectangular in section, depth uniform, breadth parabolic, fig. 63.

3. Hollow rectangular, or double-flanged, breadth uniform, depth parabolic, not reckoning webs, fig. 64.

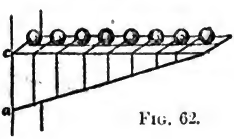



FIG. 62.

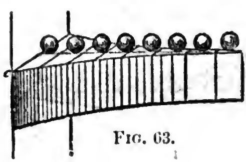



FIG. 63.

4. Hollow rectangular, or double-flanged, depth uniform, breadth parabolic, fig. 65.

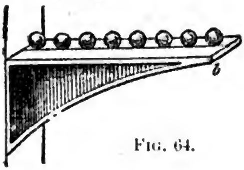


FIG. 64.

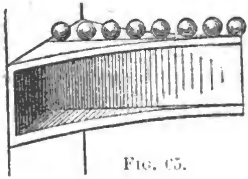


FIG. 65.

5. Section circular. The form is generated by the revolution of a semi-cubic parabola on its axis.

6. Section annular, conical form.

3. *Beams of uniform strength, loaded at the middle.*

1. Rectangular in section, breadth uniform, depth double-parabolic.

2. Rectangular in section, depth uniform, breadth double-triangular.

3. Hollow rectangular or double-flanged, breadth uniform, depth double-triangular, figs. 66, 67.

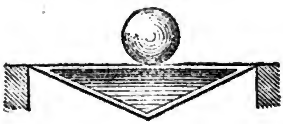


FIG. 66.

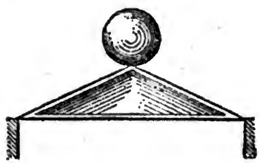


FIG. 67.

4. Hollow rectangular or double-flanged, depth uniform breadth double-triangular, fig. 68.

5. Circular section ; form double-parabolic, fig. 69.

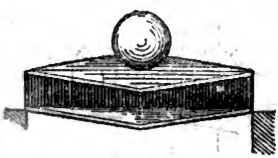


FIG. 68.

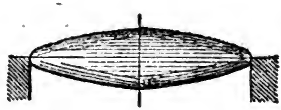


FIG. 69.

4. *Beams of uniform strength, uniformly loaded.*

1. Rectangular section, breadth uniform, depth elliptical.
2. Rectangular section, depth uniform, breadth double-

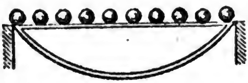


FIG. 70.

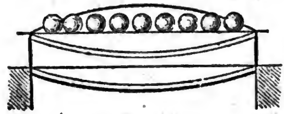


FIG. 71.

parabolic ; two parabolas having their vertices at the middle, and meeting at the points of support.

3. Hollow rectangular or double-flanged, breadth uniform, depth parabolic, fig. 70.
4. Hollow rectangular or double-flanged, depth uniform, breadth double-parabolic, fig. 71.

## Approximate Deflection of Beams

In a beam of uniform depth and uniform strength, the form assumed under the load is that of a circular arc.

Let $l$ = length of the span, or distance between the supports.
$b$ = breadth of the beam at the middle.
$d$ = depth of the beam at the middle.
E = coefficient of elasticity, or the denominator of the fraction of the length by which the beam is extended or compressed per ton of direct stress per square inch of section.
D = deflection of beam, at middle.

## Deflection of Beams of Rectangular Section, supported at each End.

1. Rectangular section, of uniform strength, depth uniform, double-triangular in plan, load at the middle :—

$$D = \frac{Wl^3}{4{\cdot}67bd^3E} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (22)$$

This formula signifies that the deflection varies directly as the weight, and as the cube of the span ; and that it varies inversely as the breadth, and as the cube of the depth, and as the coefficient of elasticity.

2. Rectangular beam, of uniform strength, breadth uniform, depth parabolic; load at the middle.

$$D = \frac{Wl^3}{3{\cdot}11bd^3E} \quad . \quad . \quad . \quad . \quad . \quad . \quad (23)$$

3. Rectangular beam, of uniform section; load at the middle.

$$D = \frac{Wl^3}{4{\cdot}57bd^3E} \quad . \quad . \quad . \quad . \quad . \quad . \quad (24)$$

4. Rectangular beam, of uniform strength; depth uniform, uniformly loaded.

$$D = \frac{Wl^3}{9{\cdot}33bd^3E} \quad . \quad . \quad . \quad . \quad . \quad . \quad (25)$$

5. Rectangular beam, of uniform strength, breadth uniform; elliptic in depth; uniformly loaded.

$$D = \frac{Wl^3}{7{\cdot}47bd^3E} \quad . \quad . \quad . \quad . \quad . \quad . \quad (26)$$

6. Rectangular beam, of uniform section; uniformly loaded.

$$D = \frac{Wl^3}{7{\cdot}47bd^3E} \quad . \quad . \quad . \quad . \quad . \quad . \quad (27)$$

**Deflection of Double-flanged or Hollow Rectangular Beams: Equal Flanges.**

7. Double-flanged beam, of uniform strength; uniform depth, double-triangular in breadth; load at the middle.

*Case* 1. When the strength of both the flanges and the web is calculated:—

$$D = \frac{Wl^3}{4d''^2E(4a + 1{\cdot}167a'')} \quad . \quad . \quad . \quad . \quad (28)$$

$d''$ = distance apart between centres of flanges.
$a$ = sectional area of one flange.
$a''$ = sectional area of the web, reckoned equal in height to $d''$.

From this equation it is inferred that the deflection varies inversely as a power of the depth greater than the square, and less than the cube.

*Case* 2. When the strength of the flanges alone is calculated:—

$$D = \frac{Wl^3}{16ad''^2E} \quad . \quad . \quad . \quad . \quad . \quad . \quad (29)$$

8. Double-flange beam, of uniform strength, of uniform breadth, triangular in depth; loaded at the middle (figs. 66, 67).

*Case* 1. When the strength of both the flanges and the web is calculated:—

$$D = \frac{Wl^3}{2d''^2E(4a + 1{\cdot}167a'')} \quad . \quad . \quad . \quad . \quad . \quad (30)$$

*Case* 2. When the strength of the flanges alone is calculated:—

$$D = \frac{Wl^3}{8ad''^2E} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (31)$$

9. Double-flange beam, of uniform section, loaded at the middle. See No. 7, formulæ 28 and 29.

10. Double-flange beam, of uniform strength, of uniform depth, breadth parabolic; uniformly loaded.

*Case* 1. When the strength of both the flanges and the web is calculated:—

$$D = \frac{Wl^3}{8d''^2E(4a + 1{\cdot}167a'')} \quad . \quad . \quad . \quad . \quad . \quad (32)$$

*Case* 2. When the strength of the flanges only is calculated:—

$$D = \frac{Wl^3}{32ad''^2E} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (33)$$

11. Double-flange beam, of uniform strength, of uniform breadth, depth parabolic; uniformly loaded (fig. 70).

*Case* 1. When the strength of both the flanges and the web is calculated:—

$$D = \frac{Wl^3}{5{\cdot}33d''^2E(4a + 1{\cdot}167a'')} \quad . \quad . \quad . \quad . \quad . \quad (34)$$

*Case* 2. When the strength of the flanges only is calculated:—

$$D = \frac{Wl^3}{21{\cdot}33ad''^2E} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (35)$$

12. Double-flange beam, of uniform section, uniformly loaded.

*Case* 1. When the strength of both the flanges and the web is calculated:—

$$D = \frac{Wl^3}{6{\cdot}4d''^2E(4a + 1{\cdot}167a'')} \quad . \quad . \quad . \quad . \quad . \quad (36)$$

*Case* 2. When the strength of the flanges only is calculated :—

$$D = \frac{Wl^3}{25{\cdot}6d''^2E} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (37)$$

*Note.*—The last-named beam—of uniform section, uniformly loaded—is the most frequently occurring in practice, in the character of rolled wrought-iron joists.

### Transverse Strength of Uniform Hollow Cylindrical Beams.

The transverse strength of a hollow cylinder is, of course, less than that of a solid cylinder of the same external diameter. The following coefficients may be substituted in formula (16) here repeated, with its converse, to find approximately the ultimate transverse strength of hollow cylinders, having bores of from $\frac{1}{8}$th to $\frac{7}{8}$ths of the external diameter of the cylinder :—

***Solid cylindrical beam.***

$$W = \frac{{\cdot}726d^3s}{l} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (38)$$

$$s = \frac{Wl}{{\cdot}726d^3} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (39)$$

*Coefficients to be substituted in the formula for bores of various proportions.*

| | Coefficient. | In parts of that of solid beam. Per cent. |
|---|---|---|
| Solid cylindrical beam . . . . . | ·726 | 100 |
| Hollow cylindrical beam, bore $\frac{1}{8}$th of external diameter (40) . . . . | ·689 | 95 |
| „ „ „ „ $\frac{1}{4}$ „ | ·614 | 84·6 |
| „ „ „ „ $\frac{3}{8}$ „ | ·535 | 73·7 |
| „ „ „ „ $\frac{1}{2}$ „ | ·452 | 62·2 |
| „ „ „ „ $\frac{5}{8}$ „ | ·365 | 50·3 |
| „ „ „ „ $\frac{3}{4}$ „ | ·269 | 37·0 |
| „ „ „ „ $\frac{7}{8}$ „ | ·160 | 22·0 |

### Torsional Strength of Bars and Shafts.

The resistance of shafting to twisting or torsional stress is dependent upon its resistance to shearing stress. The ultimate torsional resistance of a uniform cylindrical bar or shaft is expressed by the following formulæ :—

*Torsional Strength of a solid cylindrical shaft.*

$$WR = \cdot 196 d^3 s \qquad (40)$$

$$W = \frac{\cdot 196 d^3 s}{R} \qquad (41)$$

The ultimate torsional resistance of a hollow cylindrical shaft is expressed by the formulæ :—

*Torsional Strength of a hollow cylindrical shaft.*

$$WR = \frac{\cdot 196(d^4 - d'^4)s}{d} \qquad (42)$$

$$W = \frac{\cdot 196(d^4 - d'^4)s}{Rd} \qquad (43)$$

$W$ = force applied at the end of the radius R, in tons.
$R$ = length of radius at the end of which the force W is applied, at right angles, in inches.
$d$ = diameter of the bar or shaft, in inches.
$d'$ = diameter of the interior of a hollow shaft in inches.
$b$ = breadth of side of square shaft.
$s$ = ultimate shearing resistance, in tons per square inch of section.

When the section of a hollow bar, as a tube, is thin, comparatively to the diameter, the following formula may be employed :—

*Torsional Strength of a thin tube.*

$$WR = 1 \cdot 571 d^2 ts \qquad (44)$$

$$W = \frac{1 \cdot 571 d^2 ts}{R} \qquad (45)$$

*Torsional Strength of a solid square bar or shaft.*

$$WR = \cdot 281 b^3 s \qquad (46)$$

$$W = \frac{\cdot 281 b^3 s}{R} \qquad (47)$$

TABLE 173.—ULTIMATE STRENGTH OF COLUMNS OF VARIOUS CONSTRUCTION, WITH FLAT ENDS.

| Description of Column. | Formula. | Authority. |
|---|---|---|
| 1. Round cast-iron, solid or hollow . . . . . | $W = \dfrac{36a}{1 + \dfrac{r^2}{400}}$ | Gordon. |
| 2. Rectangular cast-iron, solid or hollow . . | $W = \dfrac{36a}{1 + \dfrac{r^2}{500}}$ | Gordon. |
| 3. Rectangular wrought-iron, solid . . . | $W = \dfrac{16a}{1 + \dfrac{r^2}{3000}}$ | Stoney. |
| 4. Angle, tee, channel, or cruciform iron . . | $W = \dfrac{19a}{1 + \dfrac{r^2}{900}}$ | Unwin. |
| 5. Solid round, mild steel . | $W = \dfrac{3a}{1 + \dfrac{r^2}{1400}}$ | Baker. |
| 6. Solid round, strong steel . | $W = \dfrac{51a}{1 + \dfrac{r^2}{900}}$ | Baker. |
| 7. Solid rectangular, mild steel . . . . . | $W = \dfrac{30a}{1 + \dfrac{r^2}{2480}}$ | Baker. |
| 8. Solid rectangular, strong steel . . . . . | $W = \dfrac{51a}{1 + \dfrac{r^2}{1600}}$ | Baker. |

$W$ = breaking weight, in tons.
$a$ = sectional area of the material, in square inches.
$r$ = ratio of length to diameter. The diameter for calculation is the shortest diameter of the section.

**Transverse Strength of Railway Rails.**

The ordinary double-head rail, having heads of equal form and size, may be separated into the web for the whole depth, and the flange or overhung portion. The sectional area of

the flange portions can be ascertained by dividing them into narrow horizontal strips, calculating the area of each strip separately, and taking the sums.

*Transverse strength of a double-head rail.*

$$W = \frac{s\left(4a'\frac{d''^2}{d} + 1{\cdot}167t'd^2\right)}{l} \quad . \quad . \quad . \quad . \quad . \quad (48)$$

$W$ = breaking weight at the middle, in tons.
$a'$ = net sectional area of one flange, in inches (excluding the central portion pertaining to the web).
$d$ = total depth of the rail, in inches.
$d''$ = vertical distance apart of the centres of the flanges.
$t'$ = thickness of the web.
$l$ = length of span, between supports, in inches.
$s$ = ultimate tensile strength, in tons per square inch.

**Strength of Steel Springs.**

The elasticity or deflection of laminated springs, with the working strength, are given by the following formulæ :—

$$E = \frac{1{\cdot}66 l^3}{bt^3 n} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (49)$$

$$s = \frac{bt^2 n}{11{\cdot}3 l} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (50)$$

$$n = \frac{1{\cdot}66 l^3}{Ebt^3} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (51)$$

$E$ = elasticity, or deflection, in sixteenths of an inch per ton of load.
$s$ = working strength, or load, in tons.
$l$ = span, when loaded, in inches.
$b$ = breadth of plates, in inches, taken as uniform.
$t$ = thickness of plates, in sixteenths of an inch.
$n$ = number of plates.

*Note.*—The span and the elasticity are those due to the spring when weighted.

2. When extra thick back and short plates are used, they must be replaced by an equivalent number of plates of the ruling thickness, prior to the employment of the formulæ 49 and 50. This is found by multiplying the number of extra thick plates by the cube of their thickness, and dividing by the cube of the ruling thickness. Conversely, the number of plates of the ruling thickness given by formula 51, requi-

to be deducted and replaced by a given number of extra thick plates, are found by the same calculation.

3. It is assumed that the plates are similarly and regularly formed, and that they are of uniform breadth, and but slightly taper at the ends.

### Helical Steel Springs.

$$E = \frac{d^3 w}{CD^4} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (52)$$

E = compression or extension of one coil, in inches.
$d$ = diameter from centre to centre of steel bar constituting the spring, in inches.
$w$ = weight applied, in pounds.
D = diameter, or side of the square, of the steel bar, in sixteenths of an inch.
C = a constant, which may be taken as 22 for round steel, and 30 for square steel.

*Note.*—The deflection E for one coil is to be multiplied by the number of free coils, to obtain the total deflection for a given spring.

The relation between the safe load, size of steel, and diameter of coil, may be taken for practical purposes as follows: —

$$D = \sqrt[3]{\frac{wd}{3}}, \text{ for round steel} \quad . \quad . \quad (52a)$$

$$D = \sqrt[3]{\frac{wd}{4 \cdot 29}}, \text{ for square steel} \quad . \quad . \quad (52b)$$

## STRENGTH OF TIMBER.

### Mr. Laslett's Experiments.

From the results of these experiments, the Table 174—of the direct ultimate tensile and compressive strengths of timbers—has been compiled. For tensile strengths, the specimens were 2 inches square, and usually had a clear length of 30 inches. For compressive or crushing strength, the specimens were cubes of from 1 inch to 4 inches; and pieces 2 inches square and upwards, of various lengths. The crushing resistance of 1-inch, 2-inch, 3-inch, and 4-inch cubes of various woods, was practically the same per square inch of the upper surface, though there was a slight difference in favour of the smaller cubes.

TABLE 174.—TENSILE AND COMPRESSIVE STRENGTH OF TIMBER.

| Woods. | Specific Gravity. | Tensile Resistance per Square Inch. | Crushing Resistance per Square Inch. |
|---|---|---|---|
| | Water = 1. | Tons. | Tons. |
| Oak, English | ·858, ·895 | 1·713, 3·380 | 3·337 |
| „ French | ·976 | 3·617 | 3·547 |
| „ Dantzig | ·838 | 1·882 | 3·344 |
| „ American White | ·969 | 3·143 | 2·709 |
| „ African (or Teak) | ·971 | 3·148 | ... |
| Teak, Moulmein | ·777 | 1·474 | 2·559 |
| Iron Wood, Burmah | 1·176 | 4·311 | 5·208 |
| Greenheart | 1·141 | 3·937 | 6·438 |
| Sabicu | ·917 | 2·481 | 3·776 |
| Mahogany, Spanish | ·765 | 1·692 | 2·863 |
| „ Honduras | ·659 | 1·338 | 2·853 |
| Eucalyptus, Tewart | 1·169 | 4·591 | 4·174 |
| „ Mahogany | ·996 | 1·312 | 3·198 |
| „ Iron Bark | 1·150 | 3·740 | 4·601 |
| „ Blue Gum | 1·049 | 2·700 | 3·078 |
| Ash, English | ·750 | 1·687 | 3·109 |
| „ Canadian | ·588 | 2·453 | 2·453 |
| Beech | ·705 | 2·166 | ... |
| Elm, English | ·642 | 2·437 | 2·583 |
| „ Rock, Canada | ·748 | 4·100 | 3·832 |
| Hornbeam | ·819 | 2·860 | 3·711 |
| Fir, Dantzig | ·603 | 1·442 | 3·102 |
| „ Riga | ·553 | 1·808 | 2·342 |
| „ Spruce | ·484 | 1·756 | 2·166 |
| Larch, Russia | ·649 | 1·876 | 2·596 |
| Cedar | ·469 | 1·281 | 2·000 |
| Red Pine | ·553 | 1·207 | 2·537 |
| Yellow Pine | ·551 | 1·120 | 1·877 |
| Pitch Pine | ·659 | 2·083 | 2·885 |
| Kauri Pine | ·544 | 1·803 | 2·867 |

The elastic tensile strength of timber is equal to, or nearly equal to, the ultimate tensile strength. Of Baltic timber, the elastic compressive strength is from 80 per cent. to 90 per cent. of the ultimate compressive resistance.

**Columns of Timber.**

From observations of the crushing resistance of columns

wood, Mr. Laslett deduced that the maximum resistance of square pieces to compression is exerted when the sectional area in square inches is to the length in inches proportionally as 4 is to 5, for equal seasoning and equal specific gravities. In this ratio, the maximum resistance to crushing of 12-inch square balks on end, would be exerted for a length of 15 feet.

### Timber Piles.

TABLE 175.—ULTIMATE STRENGTH OF TIMBER COLUMNS. (Brereton and Stoney.)

| Ratio of Length to Least Breadth. | Ultimate Weight that can be borne per Square Foot of Section. | Ratio of Length to Least Breadth. | Ultimate Weight that can be borne per Square Foot of Section. |
|---|---|---|---|
| | Tons. | | Tons. |
| 10 | 120 | 35 | 84 |
| 15 | 118 | 40 | 80 |
| 20 | 115 | 45 | 77 |
| 25 | 100 | 50 | 75 |
| 30 | 90 | | |

### Transverse Strength of Timber Beams, of Large Scantling, supported at the Ends, Loaded at the Middle.*

Fir . . . . . $W = \frac{1{\cdot}78bd^2}{l}$ . . (53)

Red pine . . . . $W = \frac{1{\cdot}39bd^2}{l}$ . . (54)

Quebec yellow pine . $W = \frac{1{\cdot}39bd^2}{l}$ . . (55)

Pitch pine . . . $W = \frac{2{\cdot}12bd^2}{l}$ . . (56)

English oak . . . $W = \frac{1{\cdot}64bd^2}{l}$ . . (57)

French oak . . . $W = \frac{2{\cdot}24bd^2}{l}$ . . (58)

$W$ = breaking weight in tons.
$b$ = breadth in inches.
$d$ = depth in inches.
$l$ = span in inches.

* *Manual of Rules, Tables and Data*, page 550.

**Deflection of Timber Beams of large Scantling, supported at the Ends, loaded at the Middle.**

| | | |
|---|---|---|
| Fir . . . . | $D = \frac{Wl^3}{bd^3}$ . . | (59) |
| Red pine . . . | $D = \frac{Wl^3}{2434bd^3}$ . . | (60) |
| Quebec yellow pine . | $D = \frac{Wl^3}{2084bd^3}$ . . | (61) |
| Pitch pine . . . | $D = \frac{Wl^3}{2968bd^3}$ . . | (62) |
| English oak . . | $D = \frac{Wl^3}{1848bd^3}$ . . | (63) |
| French oak . . . | $D = \frac{Wl^3}{2656bd^3}$ . . | (64) |

## STRENGTH OF CAST-IRON.

The strength of cast-iron varies according to the distribution and massiveness of the metal. Thicker pieces are less strong than thinner pieces : an inequality which arises from the fact that the outer portions, at and near the surface of a casting, are denser, harder, and stronger than the central portions.

The tensile strength of cast-iron may be taken generally as equal to from 6 tons to 7 tons per square inch of section. Dr. Anderson deduced an average of 6 tons from a long series of tests. Mr. Hodgkinson, comparing the tensile strengths of bars of cast-iron 1 inch, 2 inches, and 3 inches square, found that they were relatively, per square inch, as 100, 66, and 60.

The ultimate compressive strength of cast-iron was determined by Mr. Hodgkinson to average 38½ tons per square inch.

The tensile strength of cast-iron is increased by re-melting. Sir Frederick Bramwell proved that the tensile strength of Acadian iron was increased from 7½ tons to 18½ tons by 8 hours of continued fusion and re-melting. The compressive strength averaged 3½ times the tensile strength. Sir Wm. Fairbairn increased the compressive strength of Eglinton hot-blast iron from 44 tons to 88 tons per square inch.

Cast-iron under tension or compression does not exhibit any well-defined elastic limit. Mr. Hodgkinson tested 1-inch square bars of cast-iron, 10 feet long, under a load of 5 tons in tension, the bar extended $\frac{1}{974}$th part of its length; under the same load in compression, the bar extended $\frac{1}{1105}$th part of its length. In round numbers, it may be taken that elastic extension and elastic compression are each approximately $\frac{1}{1000}$th part of the length, under a stress of 5 tons per square inch, or $\frac{1}{5000}$th part of the length per ton per square inch, which is more than twice the rate of elastic extension of iron or of steel.

### *Influence of High Temperature.*

Cast-iron of average quality loses strength when heated above 120° F.; and it becomes insecure at the freezing-point. At a red heat, its normal strength is reduced one-third.

### *Malleable Cast-iron.*

Cast-iron is rendered malleable by the extraction of part of the constituent carbon, approximating it to wrought-iron. The tensile strength of annealed malleable cast-iron is equivalent to over 25 tons per square inch; and 10 tons load per square inch is borne without distortion.

### *Columns.*

TABLE 176.—SAFE LOAD ON HOLLOW CAST-IRON COLUMNS, WITH FLAT ENDS AND BASE PLATES: LENGTH = 20 TO 30 DIAMETERS.

(Shields.)

| Thickness. | Load per Square Inch of Sectional Area of Metal. | |
|---|---|---|
| | Length 20 to 24 Diameters. | 25 to 30 Diameters. |
| Inch. | Tons. | Tons. |
| $\frac{3}{4}$ and upwards | 2 | $1\frac{3}{4}$ |
| $\frac{5}{8}$ | $1\frac{3}{4}$ | $1\frac{1}{2}$ |
| $\frac{1}{2}$ | $1\frac{1}{2}$ | $1\frac{1}{4}$ |
| $\frac{3}{8}$ | $1\frac{1}{4}$ | 1 |

**TABLE 177.—WEIGHT AND SAFE LOAD OF CAST-IRON COLUMNS, NOT EXCEEDING 20 DIAMETERS IN LENGTH.**

(Load, two tons per square inch of sectional area.)

| Thickness of Metal. | Mean External Diameter of Column, in Inches. | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 3 | | | $3\frac{1}{2}$ | | | 4 | | | $4\frac{1}{2}$ | | | 5 | | |
| | Area. | Weight per Lineal Foot. | Safe Load. | Area. | Weight per Lineal Foot. | Safe Load. | Area. | Weight per Lineal Foot. | Safe Load. | Area. | Weight per Lineal Foot. | Safe Load. | Area. | Weight per Lineal Foot. | Safe Load. |
| Ins. | Sq. Ins. | Lbs. | Tons. | Sq. Ins. | Lbs. | Tons. | Sq. Ins. | Lbs. | Tons. | Sq. Ins. | Lbs. | Tons. | Sq. Ins. | Lbs. | Tons. |
| Solid | 7·07 | 22·2 | 14·1 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| 1 | 6·28 | 19·8 | 12·6 | 7·85 | 24·7 | 15·7 | 9·42 | 29·7 | 18·8 | 10·99 | 34·6 | 22·0 | 12·57 | 39·6 | 25·1 |
| $1\frac{1}{4}$ | ... | ... | ... | 8·84 | 27·8 | 17·7 | 10·80 | 34·0 | 21·6 | 12·76 | 40·2 | 25·5 | 14·73 | 46·4 | 29·5 |
| $1\frac{1}{2}$ | ... | ... | ... | ... | ... | ... | ... | ... | ... | 14·14 | 44·5 | 28·3 | 16·49 | 51·9 | 33·0 |
| | $5\frac{1}{2}$ | | | 6 | | | 7 | | | 8 | | | 9 | | |
| 1 | 14·14 | 44·5 | 28·3 | 15·71 | 49·5 | 31·4 | 18·85 | 59·4 | 36·7 | 21·99 | 69·3 | 44·0 | 25·13 | 79·2 | 50·3 |
| $1\frac{1}{4}$ | 16·69 | 52·6 | 33·4 | 18·65 | 58·7 | 37·3 | 22·58 | 71·1 | 45·1 | 26·51 | 83·5 | 53·0 | 30·43 | 95·8 | 60·9 |
| $1\frac{1}{2}$ | 18·85 | 59·4 | 37·7 | 21·21 | 66·8 | 42·4 | 25·92 | 81·6 | 51·8 | 30·63 | 96·5 | 61·3 | 35·34 | 111·3 | 70·7 |
| $1\frac{3}{4}$ | 21·35 | 67·2 | 42·7 | 23·36 | 73·6 | 46·7 | 28·86 | 90·9 | 57·7 | 34·36 | 108·2 | 68·7 | 39·86 | 123·6 | 79·7 |
| 2 | ... | ... | ... | 25·13 | 79·2 | 50·3 | 31·42 | 99·0 | 62·8 | 37·70 | 118·7 | 75·4 | 43·98 | 138·5 | 88·0 |
| $2\frac{1}{4}$ | ... | ... | ... | ... | ... | ... | 33·57 | 105·7 | 67·1 | 40·64 | 128·0 | 81·3 | 47·71 | 150·3 | 95·4 |
| $2\frac{1}{2}$ | ... | ... | ... | ... | ... | ... | ... | ... | .. | 43·20 | 136·1 | 86·4 | 51·05 | 160·8 | 102·1 |

TABLE 177.—CAST-IRON COLUMNS (*continued*).

| Thickness of Metal. | Mean External Diameter of Column, in Inches. | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 5½ | | | 6 | | | 7 | | | 8 | | | 9 | | |
| | Area. | Weight per Lineal Foot. | Safe Load. | Area. | Weight per Lineal Foot. | Safe Load. | Area. | Weight per Lineal Foot. | Safe Load. | Area. | Weight per Lineal Foot. | Safe Load. | Area. | Weight per Lineal Foot. | Safe Load. |
| Ins. | Sq. Ins. | Lbs. | Tons. | Sq. Ins. | Lbs. | Tons. | Sq. Ins. | Lbs. | Tons. | Sq. Ins. | Lbs. | Tons. | Sq. Ins. | Lbs. | Tons. |
| 2¾ | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 54·00 | 170·1 | 108·0 |
| 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 56·55 | 178·1 | 113·1 |
| | 10 | | | 11 | | | 12 | | | 13 | | | 14 | | |
| 1 | 28·27 | 89·0 | 56·5 | 31·42 | 99·0 | 62·8 | 34·56 | 108·9 | 69·1 | 37·70 | 118·7 | 75·4 | 40·84 | 128·6 | 80·7 |
| 1¼ | 34·36 | 108·2 | 68·7 | 38·29 | 120·6 | 76·6 | 42·21 | 133·0 | 84·4 | 46·14 | 145·3 | 92·3 | 50·07 | 157·7 | 100·1 |
| 1½ | 40·06 | 126·2 | 80·1 | 44·77 | 141·0 | 89·5 | 49·48 | 155·9 | 99·0 | 54·19 | 170·7 | 108·4 | 58·90 | 185·5 | 116·8 |
| 1¾ | 45·36 | 142·9 | 90·7 | 50·85 | 160·2 | 101·7 | 56·35 | 177·5 | 112·7 | 61·85 | 194·8 | 123·7 | 67·35 | 211·1 | 134·7 |
| 2 | 50·27 | 158·3 | 100·5 | 56·55 | 178·1 | 113·1 | 62·83 | 197·9 | 125·7 | 69·11 | 217·7 | 138·2 | 75·40 | 237·5 | 150·8 |
| 2¼ | 54·78 | 172·5 | 109·6 | 61·85 | 194·8 | 123·7 | 68·92 | 217·1 | 137·8 | 75·99 | 239·4 | 152·0 | 83·06 | 261·6 | 166·1 |
| 2½ | 58·90 | 185·5 | 117·8 | 66·76 | 210·3 | 133·5 | 74·51 | 234·7 | 149·0 | 82·47 | 259·8 | 164·9 | 89·32 | 281·3 | 178·6 |
| 2¾ | 62·64 | 197·3 | 125·3 | 71·27 | 224·5 | 142·5 | 79·91 | 251·7 | 159·8 | 88·55 | 278·9 | 177·1 | 97·19 | 306·1 | 194·4 |
| 3 | 65·97 | 207·8 | 131·9 | 75·40 | 237·5 | 150·8 | 84·72 | 266·9 | 169·4 | 94·25 | 296·9 | 188·5 | 103·67 | 326·5 | 206·3 |
| | 15 | | | 16 | | | 17 | | | 18 | | | 19 | | |
| 1 | 43·98 | 138·5 | 88·0 | 47·12 | 138·5 | 94·2 | 50·16 | 158·0 | 100·3 | 53·40 | 168·2 | 106·8 | 56·54 | 178·1 | 113·1 |
| 1¼ | 54·00 | 170·1 | 108·0 | 57·92 | 182·4 | 115·8 | 61·85 | 194·8 | 123·7 | 65·78 | 207·2 | 131·6 | 69·70 | 219·5 | 139·4 |

TABLE 177.—CAST-IRON COLUMNS (*continued*).

| Thickness of Metal. | Mean External Diameter of Column, in Inches. 15 | | | 16 | | | 17 | | | 18 | | | 19 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Area. | Weight per Lineal Foot. | Safe Load. | Area. | Weight per Lineal Foot. | Safe Load. | Area. | Weight per Lineal Foot. | Safe Load. | Area. | Weight per Lineal Foot. | Safe Load. | Area. | Weight per Lineal Foot. | Safe Load. |
| Ins. | Sq. Ins. | Lbs. | Tons. | Sq. Ins. | Lbs. | Tons. | Sq. Ins. | Lbs. | Tons. | Sq. Ins. | Lbs. | Tons. | Sq. Ins. | Lbs. | Tons. |
| 1½ | 63·62 | 200·4 | 127·2 | 68·33 | 215·2 | 136·7 | 73·04 | 230·1 | 146·1 | 77·75 | 245·9 | 155·5 | 82·47 | 259·8 | 164·9 |
| 1¾ | 73·03 | 230·0 | 146·1 | 78·34 | 246·7 | 156·7 | 83·84 | 264·1 | 167·7 | 89·34 | 281·4 | 178·7 | 94·83 | 298·7 | 189·7 |
| 2 | 81·68 | 257·3 | 162·4 | 87·96 | 277·1 | 175·9 | 94·25 | 296·9 | 188·5 | 100·53 | 316·7 | 201·1 | 106·81 | 336·4 | 213·6 |
| 2¼ | 90·12 | 283·9 | 180·2 | 97·19 | 306·1 | 194·4 | 104·26 | 328·4 | 208·5 | 111·33 | 350·7 | 222·7 | 118·40 | 373·0 | 236·8 |
| 2½ | 98·17 | 308·2 | 196·3 | 106·03 | 334·0 | 212·1 | 113·88 | 358·7 | 227·8 | 121·74 | 383·48 | 243·5 | 129·60 | 408·4 | 259·2 |
| 2¾ | 105·83 | 323·4 | 211·7 | 114·47 | 360·6 | 228·9 | 123·11 | 387·8 | 246·2 | 131·75 | 415·01 | 263·5 | 140·40 | 442·3 | 280·8 |
| 3 | 113·10 | 356·3 | 226·2 | 122·52 | 385·9 | 245·0 | 131·95 | 415·6 | 263·9 | 141·37 | 445·3 | 282·7 | 150·80 | 475·0 | 301·6 |

| Thickness of Metal. | 20 | | | 21 | | | 22 | | | 23 | | | 24 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 59·69 | 188·0 | 119·3 | 62·83 | 197·9 | 125·7 | 65·97 | 207·8 | 131·9 | 69·11 | 217·7 | 138·2 | 72·26 | 227·6 | 144·5 |
| 1¼ | 73·63 | 231·9 | 147·3 | 77·56 | 244·3 | 155·1 | 81·48 | 256·6 | 162·9 | 85·41 | 269·0 | 170·8 | 89·34 | 281·4 | 178·7 |
| 1½ | 87·18 | 274·6 | 174·4 | 91·89 | 289·4 | 183·8 | 96·61 | 304·3 | 193·2 | 101·31 | 319·1 | 202·6 | 106·03 | 334·0 | 212·1 |
| 1¾ | 100·33 | 311·5 | 200·7 | 105·83 | 323·4 | 211·7 | 111·33 | 350·7 | 222·7 | 116·83 | 368·0 | 233·7 | 122·32 | 385·3 | 244·6 |
| 2 | 113·1 | 356·2 | 226·2 | 119·38 | 376·0 | 238·7 | 125·66 | 395·8 | 251·3 | 131·94 | 415·6 | 263·9 | 138·23 | 435·4 | 276·5 |
| 2¼ | 125·47 | 395·2 | 251·9 | 132·54 | 417·5 | 265·1 | 139·60 | 439·7 | 279·2 | 146·67 | 462·0 | 293·3 | 153·74 | 494·3 | 307·5 |
| 2½ | 137·44 | 432·9 | 274·9 | 145·30 | 457·7 | 290·6 | 153·15 | 482·4 | 306·3 | 161·01 | 507·2 | 322·0 | 168·86 | 531·9 | 337·7 |
| 2¾ | 149·03 | 469·4 | 298·1 | 157·67 | 496·7 | 315·3 | 166·30 | 523·8 | 332·6 | 174·95 | 551·1 | 349·9 | 183·59 | 578·3 | 367·1 |
| [illegible] | 160·22 | 504·7 | 320·4 | 169·65 | 534·4 | 339·3 | 179·07 | 564·1 | 358·1 | 188·50 | 593·8 | 377·0 | 197·92 | 623·4 | 395·8 |

### Transverse Strength of Cast-Iron.

The strength of beams of cast-iron varies very much according to the scantling. The breaking weight of 1-inch square bars of cast-iron supported at the ends, loaded at the middle, as tested by Mr. Barlow, and subsequently by Mr. Robert Stephenson, was expressed by the formula (65)

$$W = \frac{bd^2}{l} \times 13\cdot6 \quad . \quad . \quad . \quad . \quad (65)$$

in which W is the breaking weight in tons, and $b$, $d$, and $l$, are the breadth, depth, and length of span in inches. With 12 for a co-efficient, the formula shows that the breaking weight of a 1-inch square bar, at 12 inches of span, is just one ton; and if the span be expressed in feet, the formula (66) becomes

$$W = \frac{bd^2}{l} \quad . \quad . \quad . \quad . \quad (66)$$

in which $b$ and $d$ are in inches, and $l$ in feet.

For the reason given, no constant coefficient can be employed with accuracy. The subjoined formulæ (67) and (68) give results which may safely be taken; for a minimum factor of 7 tons tensile strength per square inch, with a wide margin in excess.

*Ultimate strength of rectangular bars of ordinary cast-iron, freely supported, loaded at the middle.*

$$W = \frac{8bd^2}{l} \quad . \quad . \quad . \quad . \quad . \quad (67)$$

*Ultimate strength of round bars of cast-iron.*

$$W = \frac{5d^3}{l} \quad . \quad . \quad . \quad . \quad . \quad (68)$$

W, load in tons; $b$, $d$, and $l$ in inches.

### Deflection of Cast-iron Rectangular Bars of Uniform Section Loaded at the Middle.

$$D = \frac{Wl^3}{28000bd^3} \quad . \quad . \quad . \quad . \quad (69)$$

D the deflection, and $b$, $d$, and $l$ the breadth, depth, and span; all in inches.

### Torsional Strength of Cast-Iron.

Solid round shaft . . $WR = 1{\cdot}372d^3$ . . (70)

Hollow round shaft . . $WR = \dfrac{1{\cdot}372(d^4 - d'^4)}{d}$ . . (71)

Square shaft . . . $WR = 1{\cdot}967b^3$ . . . (72)

$W$ = force applied, in tons.
$R$ = radius of force, in inches.
$d$ and $d'$ = external and internal diameters, in inches.
$b$ = side of square, in inches.

These formulæ are based on a tensile strength of cast-iron equal to 7 tons per square inch.

## STRENGTH OF WROUGHT-IRON.

*Mr. D. Kirkaldy's Early Experiments.*

From the original and extensive results of Mr. David Kirkaldy's test-trials of bars and plates for tensile strength, the following summary results are obtained. His specimen bars were formed with a head at each end, with a clear length of 7 inches. The elongation or extension of the bars is added:

TABLE 178.—ULTIMATE TENSILE STRENGTH OF ROUND BAR IRON. (Mr. Kirkaldy.)

| Bars. | Tons per Square Inch. | Extension before Fracture. |
|---|---|---|
| Yorkshire rolled bars . . . . | 27·39 | 25·2 per cent. |
| Staffordshire " . . . . . . | 25·90 | 23·5 " |
| Lanarkshire " . . . . | 26·55 | 19·4 " |
| Rivet Iron " . . . . . | 26·00 | 20·5 " |
| Average . . . . | 26·46 | 22·2 per cent. |
| Hammered scrap, forged down . . | 23·85 | 24·8 per cent. |
| Crank shaft, scrap iron, with fibre . | 20·37 | 21·8 " |
| " " across fibre . | 18·55 | 12·5 " |
| Armour plate, across fibre . . | 16·92 | 9·0 " |

The contracted sectional area of specimens tested to fracture, varied considerably, from 29·5 per cent. of the original area for Swedish charcoal iron bars to 85·2 per cent. for common Scotch iron bars. Thus—

| Iron. | Fractured Sectional Area. |
|---|---|
| Swedish charcoal | 29·5 per cent. |
| Staffordshire charcoal | 38·4 ,, |
| Yorkshire, Lowmoor | 46·3 ,, |
| Staffordshire, B. B. Scrap | 47·6 ,, |
| ,, S. C. Crown | 53·4 ,, |
| Scotch, extra best best | 58·5 ,, |
| ,, best best | 68·9 ,, |
| ,, common | 71·6 ,, |
| ,, common | 85·2 ,, |

The strength as the diameter was reduced by rolling down from $1\frac{1}{4}$ to $\frac{1}{2}$ inch, and intermediate sizes, was increased 19 per cent., or from 22·38 tons to 26·65 tons per square inch; whilst the extension was reduced from 28·3 per cent. to 23·8 per cent.

The strength of $1\frac{1}{4}$ inch rolled bars, turned down to 1 inch in diameter, was increased 5 per cent.; and the extension was augmented from 17·2 per cent. to 19·3 per cent.

Four $1\frac{1}{4}$ inch round bars, reduced by forging to 1 inch and $\frac{3}{4}$ inch in diameter, showed an increase of 4 per cent. of strength; and the extension was reduced from 24·5 per cent. to 17·3 per cent.

Five different 1 inch bars, when reheated for repair, showed 3·8 per cent. less tensile strength; and the extension was increased from 10·1 per cent. to 32·6 per cent.

Two pieces of a $\frac{3}{4}$ inch bar of iron were tested:—one in the ordinary condition; the other after having been heated to a welding heat, and cooled slowly. The strength was not materially affected, and the extension was reduced from 22·3 per cent. to 17·7 per cent.

To test the influence of intense cold, three pieces of a $\frac{3}{4}$ inch bar were tested: one at 64° F., the others at 23° F. The colder bars broke with 2·4 per cent. less load; and with an extension of 23 per cent., against 24·9 per cent. at 64° F.

To test the effect of notching a bar, several 1 inch round bars of different makes were notched or grooved to a diameter of ·7 inch, and broken at the notch; then turned down in the body to the same diameter, and broken through the body. The average tensile strengths per square inch, and the corresponding contracted sectional areas, were as follows:—

| | Tensile Strength per Square Inch. | Contracted Sectional Area. |
|---|---|---|
| Notched | 32·91 tons | 85 per cent. |
| Turned down | 27·61 ,, | 58·4 ,, |
| Rough bar | 26·04 ,, | 59·9 ,, |

Showing a remarkable excess of resistance at the notch relatively to the sectional area, and a relatively large contracted area.

The influence of screwing bolts of 1¼ inch, 1 inch, and ⅝ inch in diameter, on the tensile strength, showed 25 per cent. average reduction of tensile strength per square inch. Chased screws were weaker than screws made with dies, whilst screws cut with blunt dies were less weakened than those cut with new and sharp dies.

The influence of ordinary welded joints in several irons, showed an average of 19·4 per cent. reduction of tensile strength, varying from 2·6 per cent. to 43·8 per cent.

The effect of the sudden application of tensile stress to 1 inch round bars of iron, without blow or jerk, as against the gradual application of stress, was to reduce the load necessary to cause fracture by 18·6 per cent., with an extension of 20·1 per cent. as against 24·6 per cent. with the gradual application of the stress.

Three pieces of iron cut out of a large crank shaft, were forged down and turned to 1 inch in diameter. Tested against two other pieces cut out, and simply turned to 1 inch in diameter, they showed 20 per cent. greater strength, but reduced extension.

The influence of the removal of the skin on strength of hammered iron, was shown by two 1½ inch square bars turned down to 1 inch in diameter, the tensile strength being 5¾ per cent. more than that of 1-inch square hammered bars in their skins, with a greater degree of extension.

A 1¼-inch round bar of Bowling iron was cut into several pieces, which were turned, forged down and hardened, with the following results:—

| Diameter. | | | Tons per Sq. In. | Extension. |
|---|---|---|---|---|
| Turned to 1 inch | . . . . | | 27·15 | 28·3 per cent. |
| Forged to ·87 " | hardened in water | | 32·79 | 19·6 " |
| " " ·78 " | " | oil | 28·85 | 19·8 " |
| " " ·70 " | " | tar | 28·06 | 22·4 " |

The second of these tensile strengths, 32·79 tons per square inch, was the maximum tensile strength of iron observed by Mr. Kirkaldy.

By casehardening and cooling in water, or in oil, or slowly, an average of 8·4 per cent. reduction of tensile strength was effected, with only one-fourth of the extension.

In cold-rolling ⅞-inch bars, the tensile strength was augmented 18 per cent., and the elongation reduced to one-half. By subsequent annealing, the gain of strength disappeared.

Angle-iron, ship-strap, and beam-iron are less in tensile strength by from 1 ton to 2 tons per square inch than bar iron; and the extensions also are less.

Mr. Kirkaldy found that the density of iron was diminished by cold-rolling:—

| | Ordinary. | Cold Rolled. | Reduced. |
|---|---|---|---|
| Bar iron, specific gravity . | 7·636 | 7·582 | ·7 per cent. |
| Boiler plate „ . | 7·566 | 7·539 | ·37 „ |

The specific gravity of iron was also reduced by stretching under tensile stress:—

| | Specific Gravity. | |
|---|---|---|
| | Before stretching. | After stretching. |
| Three 1-inch Yorkshire iron bars, stretched to ·90 inch diameter. | 7·752 | 7·674 |
| Two ·83-inch Blochairn bars, stretched to ·76-inch diameter. | 7·636 | 7·569 |
| Average for five bars . | 7·760 | 7·632 |

Showing an average of ·128 reduction of specific gravity, or 1·65 per cent.

### Swedish Hammered Bar Iron.

Mr. Kirkaldy tested round bars, 3 inches, 2 inches, 1 inch, and ½ inch in diameter, with flat bars ½ inch thick, by 3 inches, 2 inches, and 1½ inches wide, for tensile strength. The round specimens had 10 inches of clear length, and the flat specimens 15 inches.

The average ultimate strength of the round bars was 20·13 tons per square inch, with an extension of 24·6 per cent.; and that of the flat bars was 21·4 tons, with an extension of 16·7 per cent. 1½ inch turned specimens had an elastic strength of 11·05 tons, about 60 per cent. of the ultimate strength, 18·80 tons.

Under compressive stress three 1½ inch round specimens, respectively 1½, 3, and 15 inches high, were crushed under a stress of 66·45, 37·90, and 12·53 tons per square inch.

A 1-inch cube failed under a load of 82·20 tons.

### French Bar Iron.

The strength of French bar iron of various denominations is given in Table 179.

TABLE 179.—FRENCH BAR IRON—TENSILE STRENGTH.
(Debauve.)

| Description. | Ultimate Strength in Tons per Square Inch. | Extension. |
|---|---|---|
| | Tons. | Per cent. |
| Creusot, No. 1, Rails | 26·03 | 10 |
| ,, No. 2, Merchant Iron | 24·00 | 15 |
| ,, No. 3, Horse-shoe Iron | 24·13 | 18 |
| ,, No. 4, Bolts and Rivets | 24·45 | 21 |
| ,, No. 5, Boiler Plates | 24·51 | 25 |
| ,, No. 6, Machinery Iron | 24·57 | 29 |
| ,, No. 7, Exceptional | 24·89 | 34 |
| Chantillon and Commentry, No. 1, Axles | 22·86 | 25 |
| ,, ,, No. 5 | 26·35 | 13 |
| Terre-Noire, La Voulte, and Bessèges: | | |
| Ordinary | 18·42 | 17 |
| Strong | 20·96 | 20 |
| Superior | 21·59 | 25 |
| Fine | 23·50 | 26 |
| Saint Étienne, granular, No. 1 | 17·78 | ... |
| ,, ,, No. 7 | 22·86 | 12 |
| ,, fibrous, No. 1 | 16·51 | 2 |
| ,, ,, No. 7 | 22·86 | 18 |
| Porte Évêque (Isère), No. 1 | 6·35 to 12·70 | ... |
| ,, ,, No. 7 | 21·59 | 18 |
| Lyons Railway Company: | | |
| No. 1, fine charcoal | 24·13 | 25 |
| No. 2, strong superior | 23·50 | 23 |
| No. 3, strong | 22·23 | 18 |
| No. 4, ordinary | 20·96 | 12 |

In general, good ordinary French wrought-iron takes a tensile breaking weight of from 22 tons to 24 tons per square inch. The limit of elasticity corresponds to 6½ tons per square inch, whilst the maximum stress allowed in construction is 6 kilogrammes per square millimetre, or 3·81 tons per square inch, about ⅙th of the ultimate strength. In compression, the elastic limit is for fine-grain iron 3·81 tons, and f· fibrous iron, 9 tons; with ultimate rupturing stresses o· tons and 51 tons respectively.

### Mr. Kirkaldy's Experiments with Iron Plates.

The tensile strength of iron plates, from $\frac{3}{8}$ inch to $\frac{3}{4}$ inch thick, in specimens $1\frac{1}{2}$ inches and 2 inches wide, is given in Table 180 :—

TABLE 180.—ULTIMATE TENSILE STRENGTH OF IRON PLATES.

(D. Kirkaldy.)

| Plates. | Tons per Square Inch. | | Extension. | |
|---|---|---|---|---|
| | With Fibre. | Across Fibre. | With Fibre. | Across Fibre. |
| | Tons. | Tons. | Per cent. | Per cent. |
| Yorkshire . . | 24·75 | 22·64 | 13·4 | 8 |
| Staffordshire . . | 23·01 | 21·40 | 9·3 | 5·3 |
| Durham . . | 22·89 | 21·39 | 9·5 | 5·2 |
| Shropshire . . | 23·37 | 19·22 | 9·6 | 2·8 |
| Lanarkshire . | 21·96 | 19·56 | 7·0 | 3·2 |
| Averages . . | 23·20 | 20·84 | 9·8 | 4·9 |

The tensile strength across the fibre is from $1\frac{1}{2}$ tons to 4 tons per square inch less than that with the fibre. The average difference is 10 per cent.

*Fractured Sectional Area of Iron Plates.*

| | With Fibre. | | Across Fibre. | | |
|---|---|---|---|---|---|
| Yorkshire . . . | 63·5 | per cent. | 79·7 | per cent. | of original area. |
| ,, . . . | 76·5 | ,, | 83·7 | ,, | ,, |
| Staffordshire S. C. Crown | 78·5 | ,, | 89·9 | ,, | ,, |
| Staffordshire Bradley . . | 84·3 | ,, | 92·0 | ,, | ,, |
| Scotch best boiler . . | 87·3 | ,, | 93·6 | ,, | ,, |
| Staffordshire best best . | 90·9 | ,, | 94·6 | ,, | ,, |
| Scotch Ship . | 95·4 | ,, | 97·5 | ,, | ,, |
| ch common | 94·4 | ,, | 98·5 | ,, | ,, |
| ages . | 84·0 | | 91·0 | | |

By cold-rolling, pieces of Blochairn plate ·345 inch thick, rolled to two-thirds of their thickness, were nearly doubled in strength, but the extension was annihilated. By annealing after cold-rolling, only 2½ tons of the gain of strength remained, and the extension was doubled.

## Krupp Iron Plates.

Mr. Kirkaldy tested a number of Krupp iron plates, and, for comparison, Lowmoor plates, ⅜ inch, ½ inch, and ⅝ inch thick, for which testing specimens 2 inches wide, 10 inches long for extension were prepared. The specimens were tested lengthwise, crosswise, annealed and unannealed. The total average results were as follows :—

| | Krupp. | Yorkshire. |
|---|---|---|
| Elastic strength per square inch | 11·2 tons | 12·2 tons |
| Ultimate ,, ,, ,, | 21·5 ,, | 20·2 ,, |
| Ratio of elastic to ultimate strength | 52·1 per cent. | 60·4 per cent. |
| Extension at 30,000 pounds per square inch | 1·94 ,, | ·85 ,, |
| Ultimate extension | 22·6 ,, | 14·8 ,, |
| Sectional area of fracture | 66·2 ,, | 81·4 ,, |

The elastic strength of the annealed specimens was from ·30 to ·60 tons less than that of the unannealed specimens.

TABLE 181.—ULTIMATE TENSILE STRENGTH OF GALVANISED IRON SHEETS.

| Thickness. | Extension in 10 Inches. | Resistance per Square Inch. |
|---|---|---|
| | Per cent. | Tons. |
| B. W. G. No. 25, with fibre | 9 | 27·4 |
| ,, ,, across fibre | 7·4 | 21·8 |
| ,, No. 23, with fibre | 8·5 | 26·2 |
| ,, ,, across fibre | 6·3 | 22·1 |
| ,, No. 21, with fibre | 9·9 | 24·6 |
| ,, ,, across fibre | 11·2 | 21·0 |

## French Plate Iron and Sheet Iron.

Iron plates and sheets are generally disposed in six classes. For example :—

| | Tensile Strength per Square Inch. | Extension. |
|---|---|---|
| Creusot :— | | |
| No. 2 . . . . . . . . . . | 21·08 tons | 6 per cent. |
| „ 3 . . . . . . . . . . | 21·40 „ | 10 „ |
| „ 4 . . . . . . . . . . | 22·03 „ | 14 „ |
| „ 5 . . . . . . . . . . | 22·10 „ | 18 „ |
| „ 6 . . . . . . . . . . | 22·61 „ | 22 „ |
| „ 7 . . . . . . . . . . | 23·30 „ | 26 „ |
| Denain and Anzin :— | | |
| No. 2 . . . . . . . . . | 19·05 tons | 3 per cent. |
| „ 3. Boilers . . . . . . | 19·05 „ | 5 „ |
| „ 4. Common for the Marine . . | 20·96 „ | 8 „ |
| „ 5. Ordinary „ „ . . | 22·22 „ | 12 „ |
| „ 6. Superior „ „ . . . | 22·86 „ | 18 „ |
| „ 7. Fine „ „ . . | 23·50 „ | 20 „ |

In general, the resistance of the plates for the marine across the grain is from $2\frac{1}{2}$ tons to $3\frac{3}{4}$ tons less than with the grain.

### Influence of Temperature on the Tensile Strength of Wrought-Iron.

According to the results of Sir Wm. Fairbairn's experiments, the strength of ordinary Staffordshire plates, either with or across the grain, remained the same for temperatures varying from 0° F. to 400° F. This higher temperature is that of steam of 235 lbs. effective pressure per square inch. At higher temperatures, the strength declined until, at a red heat, it fell from an average of 20 tons to $15\frac{1}{4}$ tons per square inch.

TABLE 182.—DECREASE IN TENSILE STRENGTH OF WROUGHT-IRON WITH RISE OF TEMPERATURE.

(Kollman.)

| Temperature. | | Decrease in Strength. | Temperature. | | Decrease in Strength. |
|---|---|---|---|---|---|
| Centigrade. | Fahrenheit. | Per cent. | Centigrade. | Fahrenheit. | Per cent. |
| ° | ° | | ° | ° | |
| 0 | 32 | ... | 600 | 1112 | 81 |
| 200 | 392 | 5 | 700 | 1292 | 84 |
| 300 | 572 | 10 | 800 | 1472 | 89 |
| [illegible] | 752 | 27 | 1000 | 1832 | 96 |
| [illegible] | 932 | 62 | | | |

M. Debauve states that the statical resistance is not affected by cold; but that the resistance to shocks is diminished by it. For temperatures from 0° C. to 100° C., or 32° F. to 212° F., there is no change; at 200° C., or 392° F., the tensile resistance is reduced 5 per cent.; at 300° C., or 572° F., reduced 10 per cent.; at 500° C., or 932° F., 60 per cent.; at 700° C., or 1292° F., 80 per cent.; at 900° C., or 1,652° F., 90 per cent.; at 1,000° C., or 1,832° F., the reduction of strength amounts to 95 per cent., leaving 5 per cent. of resisting strength. These results have been obtained for fibrous iron, fine grain iron, and Bessemer steel.

### Working Temperatures.

The leading temperatures at which iron is worked are these:—

*Brown-Red Heat*, about 700° C., or 1,300 F.: the lower limit for working iron.

*Cherry-Red Heat*, about 950° C., or 1,730° F.: iron can be dressed, or rectified.

*Red-White Heat*, about 1,300° C., or 2,370° F.; iron easily worked.

*Welding Heat*, about 1,500° C., or 2,730° F.

### Experiments of the Steel Committee of Civil Engineers, with Bar Iron.

$1\frac{1}{2}$ inch round bars of Lowmoor iron, and S. C. Crown. Staffordshire iron, were tested for tensional strength and compressive strength, to the elastic limit, as well as for ultimate tensile strength. The bars were in lengths of 10 feet, for tension and for compression.

The summary average results of the tests are given in Table 183 (p. 355).

### Transverse Strength of Wrought-Iron.

The general formula (3), page 322, as follows:—

$$W = \frac{1 \cdot 167 b d^2 s}{l} \quad . \quad . \quad . \quad . \quad (73)$$

gives the transverse strength of wrought-iron beams, supported at both ends and loaded at the middle, by substituting for $s$ the ultimate tensile strength of the metal. Taking $s = 20$ tons per square inch.

*Transverse Strength of Wrought-Iron Beams or Bars supported at both ends, loaded at the middle.*

Square or Rectangular $W = \frac{23 \cdot 3bd^2}{l}$ . . . (74)

Round . . . . $W = \frac{14 \cdot 6d^3}{l}$ . . . (75)

$W$ = load at middle, in tons.
$b$ = breadth of beam, in inches.
$d$ = depth or diameter, in inches.
$l$ = span, in inches.

For wrought-iron beams of other tensile strength, the co-efficients to be employed in equations (74) and (75), are as follows :—

| Tensile Strength. | Coefficient for Equation (74). | For Equation (75). |
|---|---|---|
| 21 tons . . . . | 24·5 | 15·3 |
| 22 " . . . . | 25·7 | 16·0 |
| 23 " . . . . . | 26·8 | 16·8 |
| 24 " . . . . . | 28·0 | 17·5 |
| 25 " . . . . . | 29·2 | 18·2 |

*Elastic Transverse Strength of Wrought-Iron.*

Rectangular section . . $D = \frac{Wl^3}{47{,}000bd^3}$ . . (76)

Round section . . . . $D = \frac{Wl^3}{32{,}000d^4}$ . . (77)

$D$ = deflection in inches.
$W$ = load at middle, in tons.
$b$ = breadth in inches.
$d$ = depth, or diameter, in inches.
$l$ = span in inches.

**Torsional Strength of Wrought-Iron Bars or Shafts.**

Taking the ultimate tensile strength of wrought-iron bars and shafts at $22\frac{1}{2}$ tons per square inch, on an average, the formulæ for the torsional strength of wrought iron are (p. 356) :—

## TABLE 183.—STRENGTH OF ROUND WROUGHT-IRON BARS, $1\frac{1}{2}$ INCHES DIAMETER, 10 FEET LONG.

(The Steel Committee.)

### I. TENSILE STRENGTH (Summary Averages).

| Description of Iron. | Elastic Strength in Tons per Square Inch. | Elastic Extension in parts of the Length. | | Breaking Weight in Tons per Square Inch. | Permanent Extension. | Ratio of Elastic to Breaking Strength. | Sectional Area of Fracture. |
|---|---|---|---|---|---|---|---|
| | | Total. | Per Ton per Square Inch. | | | | |
| | Tons. | Per cent. | Length = 1. | Tons. | Per cent. | Per cent. | Per cent. |
| Yorkshire . . . . | 13·0 | ·103, or 1 in 974 | ·000079, or $\frac{1}{12658}$ | 25·8 | 12·5 | 50·6 | 64·6 |
| S. C. Crown, Staffordshire | 11·8 | ·096, or 1 in 1046 | ·000081, or $\frac{1}{12346}$ | 22·6 | 17·5 | 52·2 | 52·3 |
| Mean . . . | 12·4 | ·100, or 1 in 1000 | ·000080, or $\frac{1}{12500}$ | 24·2 | 15·0 | 51·4 | 58·4 |

### II. COMPRESSIVE STRENGTH (Summary Averages).

| Description of Iron. | Elastic Strength in Tons per Square Inch. | Elastic Compression. | | Breaking Weight in Tons per Square Inch. | Permanent Extension. | Ratio of Elastic to Breaking Strength. | Sectional Area of Fracture. |
|---|---|---|---|---|---|---|---|
| Yorkshire . . . . | 12·6 | ·097, or 1 in 1030 | ·000077, or $\frac{1}{12987}$ | ... | ... | ... | ... |
| S. C. Crown, Staffordshire | 11·7 | ·097, or 1 in 1030 | ·000083, or $\frac{1}{12048}$ | ... | ... | ... | ... |
| Mean . . . . | 12·1 | ·097, or 1 in 1030 | ·000080, or $\frac{1}{12500}$ | ... | ... | ... | ... |

*Ultimate Torsional Strength of Wrought-Iron Bars or Shafts.*

| | | | |
|---|---|---|---|
| Round bar or shaft | $WR = 4{\cdot}41d^3$ | . . . . . | (78) |
| " " " | $d = {\cdot}283\sqrt{WH}$ | . . . . . | (79) |
| Square " " | $WR = 6{\cdot}32b^3$ | . . . . . | (80) |
| " " " | $b = {\cdot}251\sqrt[3]{WH}$ | . . . . | (81) |

The elastic torsional strength is about 40 per cent. of the ultimate torsional strength.

Torsional deflection of wrought-iron bars and shafts within the elastic limit, is given by the formula :—

*Elastic Torsional Deflection of Wrought-Iron Bars and Shafts.*

$$D = \frac{WRl}{1072d^4} \quad . \quad . \quad . \quad . \quad . \quad . \qquad (82)$$

$W$ = force in tons
$R$ = radius of force, in inches.
$WR$ = moment of force, in statical inch-tons.
$d$ = diameter of round shaft, in inches.
$b$ = side of square shaft, in inches.
$l$ = length of shaft subject to torsional action, in inches.
$D$ = total angular deflection in parts of one revolution.

## STRENGTH OF STEEL.

The qualities of iron and steel depend principally on the proportion of constituent carbon, thus :—

| | Percentage of Carbon. |
|---|---|
| Ordinary iron<br>Either soft or mild steel | 0 to 0·15 |
| Granular iron<br>Soft or mild steel | 0·15 to 0·45 |
| Steely iron or puddled steel<br>Semi-mild steel | 0·45 to 0·55 |
| Cemented steel<br>Hard steel | 0·55 to 1·50 |
| Cast-iron | 1·5 to 5 |

### Mr. Kirkaldy's Experiments.

Steel bars of from ½ inch to 1 inch in diameter were tested, and proved to from an average of 59 tons per square inch for tool steel, to an average of 29 tons for puddled steel. The

greatest observed ultimate strength was 66·2 tons per square inch for tool-steel. The general results are given in Table 184.

TABLE 184.—BAR STEEL: TENSILE STRENGTH.

(Mr. Kirkaldy—Summary.)

| Name. | Treatment. | Size. | Breaking Weight per Sq. Inch (average). | Extension. |
|---|---|---|---|---|
| | | Inch. | Tons. | Per cent. |
| Tool steel . . | Forged | ·53 to ·59 | 59·21 | 5·3 |
| Chisel steel . . | ,, | ·56 to ·60 | 55·75 | 7·1 |
| Shear steel . . | ,, | ·56 and ·57 | 52·87 | 13·5 |
| Drift steel . . | ,, | ·57 | 51·76 | 13·3 |
| Bessemer tool steel | ,, | ·65 to ·75 | 49·75 | 5·5 |
| Rivet steel . . | Rolled | ·75 | 47·75 | 10·5 |
| Blister steel . . | Forged | ·57 to ·60 | 46·56 | 9·7 |
| Steel for taps . . | ,, | ·57 and ·59 | 45·15 | 10·8 |
| Krupp's bolt steel. | Rolled | ·91 to ·93 | 41·08 | 15·3 |
| Homogeneous metal . . | ,, | ·56 | 40·47 | 13·7 |
| ,, ,, | Forged | ·75 | 40·05 | 11·9 |
| Spring steel . . | ,, | ·55 to ·57 | 32·37 | 18·0 |
| Puddled steel . . | Rolled | ·75 to 1 | 31·32 | 11·3 |
| ,, ,, . | Forged | ·75 and ·77 | 29·40 | 13·4 |

**Experiments of the Steel Committee with Bar Steel.***

In the second series of experiments made at Woolwich Dockyard the object was to make experiments on the tension of long steel bars and iron bars, measuring the changes of length directly from the bars. For this purpose 91 round bars of steel and iron, each 14 feet long, $1\frac{1}{2}$ inches in diameter, were procured, consisting of 33 bars of crucible steel, 34 bars of Bessemer steel, 12 bars of Lowmoor iron, 6 bars of best Yorkshire iron, and 6 bars of usual S. C. Crown, or Staffordshire iron. The extensions were measured on 10 feet length of each bar, and for compressive tests, the bars were cut to a length of 12 feet, and the measurements made on a length of 10 feet. The bars were tested in their natural skins. They were thoroughly examined, straightened, and gauged before being

* For a detailed notice of these important experiments, see *Manual Rules, Tables, and Data*, pages 579, 596.

TABLE 185.—STRENGTH OF STEEL BARS $1\frac{1}{2}$ INCHES IN DIAMETER, 10 FEET LONG.
(The Steel Committee.)

I. TENSILE STRENGTH (SUMMARY AVERAGES.)

| Description of Steel. | Elastic Strength in Tons per Square Inch. | Elastic Extension, in parts of the Length. Total. | Elastic Extension, in parts of the Length. Per ton per Square Inch. | Breaking Weight in Tons per Square Inch. | Permanent Extension. | Ratio of Elastic to Breaking Stress. | Sectional Area of Fracture. |
|---|---|---|---|---|---|---|---|
| | Tons. | Per cent. | Length = 1. | Tons. | Per cent. | Per cent. | Per cent. |
| Crucible . . . . | 23·4 | ·182, or 1 in 550 | ·000078, or $\frac{1}{12850}$ | 40·88 | 5·1 | 58·0 | 90·6 |
| Bessemer . . . . | 18·4 | ·144, or 1 in 695 | ·000078, or $\frac{1}{12780}$ | 34·22 | 12·0 | 53·8 | 62·5 |
| Mean . . . | 20·9 | ·163, or 1 in 613 | ·000078, or $\frac{1}{12780}$ | 37·55 | 8·5 | 55·9 | 76·6 |

II. COMPRESSIVE STRENGTH (SUMMARY AVERAGES.)

| Description of Steel. | Elastic Strength in Tons per Square Inch. | Elastic Compression. Total. | Elastic Compression. Per ton per Square Inch. | Breaking Weight | Permanent Extension | Ratio | Sectional Area |
|---|---|---|---|---|---|---|---|
| Crucible . . . . | 23·3 | ·175, or 1 in 570 | ·000076, or $\frac{1}{13250}$ | ... | ... | ... | ... |
| Bessemer . . . . | 17·8 | ·137, or 1 in 732 | ·000077, or $\frac{1}{13040}$ | ... | ... | ... | ... |
| Mean . . . | 20·5 | ·156, or 1 in 641 | ·000076, or $\frac{1}{13140}$ | ... | ... | ... | ... |
| | Bars tested for Compression, but not for Tension. | | | | | | |
| Crucible: axles, rails, tyres . . . . | 23·0 | ·172, or 1 in 581 | ·000073, or $\frac{1}{13700}$ | ... | ... | ... | ... |
| Bessemer: axles, rails, tyres . . . . | 24·0 | ·182, or 1 in 550 | ·000074, or $\frac{1}{13514}$ | ... | ... | ... | ... |

tested. The summary results have been given for bar iron, page 349, and those for the steel bars in Table 185, preceding.

The average compositions of the foregoing steels and the Yorkshire iron tested at the same time were as follows:—

| | Crucible Steel. Per cent. | Bessemer Steel. Per cent. | Yorkshire Iron. Per cent. |
|---|---|---|---|
| Iron | 98·89 | 99·20 | 99·49 |
| Carbon | ·62 | ·33 | ·23 |
| Silicon | ·114 | ·022 | ·10 |
| Manganese | ·34 | ·39 | ·08 |
| Sulphur | ·01 | ·035 | ·02 |
| Phosphorus | ·026 | ·02 | ·08 |
| | 100·000 | 99·997 | 100·00 |
| Specific gravity | 7·842 | 7·855 | 7·758 |

### Hadfield's Manganese Steel.

Though steel becomes brittle when the constituent manganese exceeds 2·75 per cent., yet it has been proved by Mr. R. A. Hadfield that when there is a proportion of not less than 7 per cent. of manganese, up to about 20 per cent., the product is a new metal, of superior strength. The Table 186 gives comparative tensile strengths and extensions of Siemens and Bessemer steels, including manganese steel of the following composition:—iron, 98·00, carbon, ·85, silicon, ·23, sulphur, ·08, phosphorus, ·09, and manganese, 13·75 per cent.

TABLE 186.—MANGANESE STEEL AND OTHER MILD STEELS.

| Description. | Breaking Loads. | Extension. |
|---|---|---|
| | Tons. | Per cent. |
| Siemens | 26·16 to 28·51 | 31·25 to 35·69 |
| Siemens | 26·26 „ 28·21 | 32·78 „ 37·50 |
| Bessemer | 20·21 „ 28·44 | 31 „ 35 |
| Siemens | 25·10 „ 27·21 | 31 „ 34 |
| Basic Bessemer | 22·20 „ 25·80 | 30 „ 34 |
| Siemens | 26·54 „ 28·29 | 28 „ 31 |
| Manganese steel | 57 „ 65 | 39·8 „ 50·7 |

TABLE 187.—COMPRESSED STEEL: TENSILE STRENGTH.
(W. H. Greenwood.)

| Description. | Elastic limit, per Sq. Inch. | Ultimate Strength per Sq. Inch. | Contraction of Area at Fracture. | Extension in Four Inches. |
|---|---|---|---|---|
| I. *Test pieces cut longitudinally*:— | Tons. | Tons. | Per cent. | Per cent. |
| Unpressed ingot. | 11·11 | 29·18 | 4·41 | 8·76 |
| Pressed ingot . | 14·45 | 29·53 | 7·90 | 12·51 |
| II. *Test pieces cut transversely*: | | | | |
| Unpressed ingot. | 11·43 | 28·04 | 3·61 | 7·91 |
| Pressed ingot . | 12·38 | 30·07 | 7·57 | 12·74 |

## Whitworth Compressed Steel.

Steel subjected by the Whitworth process to compression while fluid, under a pressure of from 4 tons to 12 tons per square inch, gains in solidity and strength. In one instance the specific gravity of sound crucible steel containing 0·54 per cent. of carbon, was increased by compression from 7·8542 to 7·8795. The density of steel as a whole is increased by from 8 per cent. to 12 per cent. by compression pressure. Two sample ingots, pressed and unpressed, contained respectively 0·5 per cent. and 0·39 per cent. of carbon, and 0·35 per cent. and 0·4 per cent. of manganese. The results of tests for tensile strength are given in Table 187, the data of which are given by Mr. W. H. Greenwood. There is practically very little difference in the strengths of pieces cut longitudinally and transversely. But there is a considerable augmentation of elastic strength by compression.

## Strength of Steel Plates.

Mr. Kirkaldy tested a number of steel plates for tensile strength, the results of which are summarised in Table 189. The plates were from $\frac{3}{16}$ inch to $\frac{5}{16}$ inch thick; and it is shown that whilst the puddled steels possessed about 10 per cent. less ultimate strength across the fibre than with it, the cast steel plates were at least as strong crosswise as lengthwise.

Landore steel plates tested by Mr. Kirkaldy were shown to have the same resisting strength lengthwise and crosswise as in the following Table 188. It is shown that the annealed samples have about $7\frac{1}{2}$ per cent. less tensile resistance than unannealed samples.

TABLE 188.—LANDORE STEEL PLATES: TENSILE STRENGTH.

| | Tensile Strength per Square Inch. | | | |
|---|---|---|---|---|
| | With the Grain. | | Across the Grain. | |
| | Annealed. | Un-annealed. | Annealed. | Un-annealed. |
| Elastic strength, tons | 12·8 | 14·5 | 12·8 | 14·4 |
| Ultimate strength „ | 28·8 | 31·1 | 28·8 | 31·2 |
| Contraction of area at fracture, p. cent. | 43·2 | 41·1 | 44·9 | 40·5 |
| Extension „ | 24·6 | 23·4 | 23·6 | 23·5 |

TABLE 189.—STEEL PLATES: TENSILE STRENGTH.

(Mr. Kirkaldy—Summary.)

| Description of Steel. | Thickness of Plate. | Breaking Weight per Square Inch. | | Extension in parts of the Length. | |
|---|---|---|---|---|---|
| | | With Fibre. | Across Fibre. | With Fibre. | Across Fibre. |
| | Inch. | Tons. | Tons. | Per cent. | Per cent. |
| Cast steel . . | $\frac{3}{16}$ to $\frac{3}{8}$ | 38·82 | 39·90 | 12·90 | 13·96 |
| Puddled steel . | $\frac{1}{8}$ to $\frac{5}{16}$ | 41·56 | 35·34 | 5·12 | 2·82 |
| Mild puddled steel . . | $\frac{1}{4}$ to $\frac{9}{32}$ | 33·16 | 30·22 | 4·90 | 5·70 |
| Hard puddled steel . . | $\frac{1}{4}$ | 45·80 | 38·11 | 4·90 | 3·30 |
| Total averages | $\frac{3}{16}$ to $\frac{3}{8}$ | 39·83 | 35·90 | 6·95 | 6·44 |

The following results of tests of hematite steel and Krupp steel are given as examples comprising ultimate compressive strength :—

| | Hematite. | Krupp. |
|---|---|---|
| Elastic tensile strength, per square inch . . . . | 18·63 tons | 19·10 tons |
| Ultimate tensile strength, per square inch . . . . | 32·27 „ | 42·07 „ |
| Extension . . . . . . | 19·2 per cent. | 7·9 per cent. |
| Elastic compressive strength . | 23·21 tons | 21·13 tons |
| Ultimate „ „ . | 71·24 „ | 89·30 „ |

**Strength of Steel as affected by its Chemical Composition.**

TABLE 190.—BESSEMER STEEL (FOR TYRES): CHEMICAL COMPOSITION AND TENSILE STRENGTH.
(J. O. Arnold—Summary.)

| Chemical Composition. | | | | | | | Tensile Strength. | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Iron. | Carbon. | Chromium. | Manganese. | Silicon. | Sulphur. | Phosphorus. | Ultimate, in Tons per Sq. Inch. | Extension. | Reduction of Area. | Fracture. |
| Per cent. | Per cent. | Per cent. | Per cent. | Per cent. | Per cent. | Per cent. | Tons. | Per cent. | Per cent. | |
| 98·24 | ·28 | ... | 1·25 | ·07 | ·08 | ·08 | 37 | 26 | 47 | Gray granular. Convex and concave. |
| 97·74 | ·25 | ... | 1·75 | ·03 | ·12 | ·11 | 42·1 | 18 | 26·3 | Gray granular, flat. |
| 97·49 | ·28 | ·42 | 1·54 | ·08 | ·10 | ·09 | 49·8 | 15 | 26 | Finely crystalline, flat. |
| 97·69 | ·32 | ·30 | 1·46 | ·11 | ·05 | ·07 | 50 | 16 | 29 | Coarse granular. |
| 97·42 | ·28 | ·64 | 1·41 | ·11 | ·07 | ·07 | 50·4 | 10 | 13·8 | Crystalline. |
| SPRING STEEL. | | | | | | | | | | |
| | | | | | | | | | | Description. |
| 98·24 | ·50 | ... | 1·10 | ·07 | ·09 | ·08 | 50·8 | 14·9 | 31·4 | Unhardened. |
| | | | | | | | 69·4 | 10·9 | 30·0 | Water hardened. |
| | | | | | | | 88·0 | 3·1 | 4·9 | Oil hardened. |

The Table 190, gives the experimental results of tests of Bessemer tyre-steel, conducted by Mr. J. O. Arnold, with the chemical composition of the steels tested. These comprise samples containing various proportions of chromium and manganese, as well as of carbon. An example of spring steel is introduced in this Table, showing the hardening influence of water and of oil.

Another Table 191, of the transverse strength of steel rails, shows also the variations of transverse strength with the percentage of carbon. The rails were double-headed, 5½ inches deep, weighing 86 pounds per yard; and whilst the carbon increased from ·40 per cent. to ·55 per cent., the ultimate loads were increased from 40 tons to 52½ tons.

TABLE 191.—TRANSVERSE STRENGTH OF STEEL RAILS IN RELATION TO THE CONSTITUENT CARBON.

Span 43·5 inches. Load applied at the middle.

| Constituent Carbon. | Ultimate Strength. | | | Elastic Strength. | | | |
|---|---|---|---|---|---|---|---|
| | Load. | Deflection. | Set. | Load. | | Deflection. | Set. |
| Per cent. | Tons. | Inch. | Inch. | Tons. | Per cent. | Inch. | Inch. |
| ·40 | 40 | 3·94 | 3·74 | 15 | 37·5 | ·10 | ·01 |
| ·46 | 40 | 2·64 | 2·34 | 20 | 50 | ·14 | ·05 |
| ·49 | 50 | 4·18 | 3·77 | 22·5 | 45 | ·165 | ·03 |
| ·50 | 52·5 | 4·68 | 4·28 | 22·5 | 43 | ·130 | ·01 |
| ·55 | 52·5 | 4·40 | 4·02 | 25 | 48 | ·165 | ·04 |

TABLE 192.—TENSILE STRENGTH OF STEEL RAILS IN RELATION TO THE CONSTITUENT CARBON.

| Constituent Carbon. | Ultimate Tensile Strength, in Tons per Square Inch. | Constituent Carbon. | Ultimate Tensile Strength, in Tons per Square Inch. |
|---|---|---|---|
| Soft Rails. | | Hard Rails. | |
| Per cent. | Tons. | Per cent. | Tons. |
| ·28 | 30·90 | ·36 | 37·01 |
| ·29 | 32·60 | ·39 | 41·41 |
| ·30 | 32·94 | ·40 | 37·68 |
| ·31 | 32·67 | ·43 | 39·10 |
| ·32 | 33·04 | ·44 | 41·02 |
| | | ·45 | 44·00 |
| | | ·50 | 45·79 |
| | | ·57 | 50·42 |

Thirty Bessemer steel rails, manufactured at Barrow-in-Furness, comprising various proportions of constituent carbon, were tested for tensile strength, with the results given by Mr. J. T. Smith in Table 192, showing that the tensile strength increased from 30·9 tons to 50·42 tons per square inch, with the proportions of carbon from ·28 to ·57 per cent.

TABLE 193.—TENSILE STRENGTH OF STEEL IN RELATION TO THE CONSTITUENT CARBON.

| Description of Steel. | Constituent Carbon (Approximate). | Breaking Weight per Square Inch. | Extension. |
|---|---|---|---|
| | Per cent. | Tons. | Per cent. |
| Webb steel . . . | ·20 | 28·0 | ... |
| Vickers No. 2 . . | ·33 | 30·4 | 9·8 |
| " No. 4 . . | ·43 | 34·0 | 9·8 |
| " No. 5 . . | ·48 | 37·5 | 8·9 |
| " No. 6 . . | ·53 | 42·5 | 8·0 |
| " No. 8 . . | ·63 | 45·0 | 7·1 |
| " No. 10 . . | ·74 | 45·5 | 5·0 |
| " No. 12 . . | ·84 | 55·0 | 8·0 |
| " No. 15 . . | 1·00 | 60·0 | 5·0 |
| " No. 20 . . | 1·25 | 69·0 | 4·4 |

The influence of the constituent carbon on the tensile strength of steel was well exemplified by Mr. T. Edward Vickers in 1861, as shown in the Table 193. To render the table fuller, the strength and constituent carbon of Mr. Webb's steel for boiler plates are prefixed, in the first line. The specimens of Mr. Vickers were made of crucible steel from Swedish iron. They were turned to a diameter of 1 inch for a clear length of 14 inches. It is shown that the ultimate tensile strength increases with the carbon from 28 tons, with $\frac{1}{5}$th per cent. of carbon, to 69 tons per square inch with $1\frac{1}{4}$ per cent. of carbon.

M. Debauve gives the following evidence of the influence of the constituent carbon, in the case of steel bars tempered in oil:—

| | |
|---|---|
| Constituent carbon | ·15, ·49, ·709, ·875 per cent. |
| Elastic limit . | 20·32, 27·94, 43·18, 57·15 tons per square inch. |

| | |
|---|---|
| Ultimate strength | 29·21, 46·45, 67·94, 67·31 tons per square inch. |
| Extension in inches . . | 28, 12, 4, 1 per cent. |

### Strength of Long Round Steel Columns.

The safe working load for long round steel columns is given by means of the following formula :—

$$W = 1400\frac{d^3}{l^2} \quad . \quad . \quad . \quad . \quad . \quad . \quad (83)$$

$W$ = safe load in cwts.
$d$ = diameter of column in inches.
$l$ = length of column between supports or brackets, in feet.

This formula is specially applicable to the case of hydraulic lifts, as well as to the case of fixed loads. It may be properly employed for columns of from 3 inches to 5 inches in diameter, and for lengths of from 25 feet up to 50 feet, for columns not less than 3 inches in diameter ; and up to 80 feet for 5-inch columns. Table 194 has been calculated by means of the above formula.

TABLE 194.—SAFE LOAD ON LONG ROUND STEEL COLUMNS.

| Diameter of Column. | Length of Column between Supports, in Feet. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 25 | 30 | 35 | 40 | 45 | 50 | 60 | 70 | 80 |
| Inches. | Cwts. | Cwts. | Cwts. | Cwts. | Cwts. | Cwts. | Cwts. | Cwts. | Cwts. |
| 3 | 60·5 | 42·0 | 30·8 | 23·6 | 18·6 | 15·1 | ... | ... | ... |
| 3¼ | 76·8 | 53·4 | 39·2 | 30·0 | 23·7 | 19·2 | ... | ... | ... |
| 3½ | 96·0 | 66·7 | 49·0 | 37·5 | 29·6 | 24·0 | 16·7 | ... | ... |
| 4 | 143·0 | 99·6 | 73·1 | 56·0 | 44·2 | 35·8 | 25·0 | ... | ... |
| 4½ | 204·1 | 141·7 | 104·1 | 79·7 | 63·0 | 51·0 | 35·4 | 26·0 | ... |
| 5 | 280·0 | 194·4 | 143·0 | 109·4 | 86·4 | 70·0 | 48·6 | 35·7 | 27·3 |

### Transverse Strength of Steel.

Taking the ordinary standard of ultimate tensile strength, 32 tons per square inch, for steel, the formula for its ultimate transverse strength is :—

*Ultimate Transverse Strength of Steel Beams of Rectangular Section, supported at the Ends, loaded at the Middle.*

$$W = \frac{37 \cdot 3bd^2}{l} \quad . \quad . \quad . \quad . \quad . \quad (84)$$

For some other values of tensile strength, the numerical coefficients annexed are to be substituted in this equation :—

| Ultimate Tensile Strength. Tons. | Coefficient. |
|---|---|
| 28 | 32·7 |
| 30 | 35·0 |
| 35 | 40·8 |
| 40 | 46·7 |
| 45 | 52·5 |
| 50 | 58·4 |

The proper coefficient for any other tensile strength is found by multiplying the strength in tons per square inch by 1·167.

*Elastic Deflection of Steel Bars or Beams, of Rectangular Section, supported at the Ends, Loaded at Middle.*

Square . . . $D = \frac{Wl^3}{56,000bd^3}$ . . . . . (85)

Round . . . $D = \frac{Wl^3}{38,000bd^3}$ . . . . . (86)

**Ultimate Torsional Strength of Steel Bars or Shafts.**

Round bar or shaft . $WR = 6{\cdot}27d^3$ . . . . . (87)

" " " . $d = {\cdot}252\sqrt[3]{WR}$ . . . . . (88)

Square bar or shaft . $WR = 8{\cdot}99b^3$ . . . . . (89)

" " " . $b = {\cdot}223\sqrt[3]{WR}$ . . . . . (90)

*Elastic Torsional Deflection of Steel Bars or Shafts.*

$$D = \frac{WRl}{152d_4} \quad . \quad . \quad . \quad . \quad . \quad (91)$$

## TENSILE STRENGTH OF COPPER, LEAD, ETC.

| | Tons per Square Inch. |
|---|---|
| Cast copper | $8\frac{1}{2}$ to $11\frac{1}{2}$ |
| Wrought copper | 15 |
| Copper bolts | 16 |
| Copper bolts, with 1 per cent. of phosphorus | 7·56 to 19·20 |
| " " 2 " " " | 20·25 |
| " " 3 " " " | 21·38 |
| " " 4 " " " | 22·32 |
| Solid drawn copper tube, 10 inches in diameter, $\frac{1}{4}$ inch thick (Broughton Copper Company) :— | |
| Unannealed (elastic limit, 16·34 tons per square inch) | 18·64 |
| Annealed ( " 5·26 " " ) | 15·35 |
| Brazed copper tubes (Mr. Mallison) :— | |
| Plain sheet used for steam pipes (35·7 per cent. extension) | 14·81 |
| Brazed and hammered . . (13·83 " " ) | 14·49 |
| Brazed, not hammered . (17·14 " " ) | 13·47 |

Drawn copper tubes, 3 inches in diameter, ·131 inch to ·093 inch thick (Goodwin & How):—

| | | Tons per Square Inch. |
|---|---|---|
| Unannealed, longitudinally | (extension 16·9 per cent.) | 18·6 |
| „ transversely | ( „ 15·2 „ ) | 18·3 |
| Annealed, longitudinally | ( „ 38·0 „ ) | 14·7 |
| „ transversely | ( „ 35·2 „ ) | 14·9 |

Elmore's deposited copper tubes (Elmore Metal Copper Depositing Company):—

For pressure purposes, tensile strength over 20 tons per square inch, with elongation of not less than 10 per cent. measured on 10 inches.

Up to 30 tons per square inch with elongation 6 per cent.

For such purposes as liners, rollers, and like articles, with elongation down to 1 per cent., with hardness stated to be greater than that of any of the brasses and bronzes which have been tested against the Elmore Metal.

Cold planishing: increase of strength:—

Solid plate, cold, ¾ per cent.
„ „ hot (from 330° to 410°) 5 per cent.
Joint, cold, 17½ per cent.
„ hot, 11½ „

Strength the same, longitudinally and transversely.

Brazed joint in plain sheet, with care in workmanship, parts of solid joint, 75 per cent.

Brazed joint in pipe, under steam of 150lb. pressure, 60 to 62 per cent.

Brazing metal: spelter, 49·15 per cent., copper, 58·85 per cent.

### Tensile Strength of Alloys of Copper.

Aluminium bronze, castings:—

| | | | Tons per Square Inch. |
|---|---|---|---|
| Copper 89, | aluminium 11 | (extension, 0 to 5 per cent.) | 45 to 50 |
| „ 90, | „ 10 | ( „ 4 to 25 „ ) | 40 to 32 |
| „ 95, | „ 5 | ( „ 35 to 50 „ ) | 15 to 21 |
| „ 97½, | „ 2½ | ( „ 45 to 60 „ ) | 12 to 15 |
| 98¾, | „ 1¼ | ( „ 20 to 35 „ ) | 9 to 12 |

Aluminium brass, castings:—

No. 1. Aluminium bronze, and zinc (extension, 10 to 14 per cent.) . . . . . . 23 to 27

No. 2. Aluminium bronze, and zinc (extension, 8 to 11 per cent.) . . . . . . 36 to 38

| | Tons per Sq. In. |
|---|---|
| Brass, fine or yellow, 2 copper, 1 zinc . . . . | 12·90 |
| Brass tube, 62 copper, 38 zinc . . . . . . | 46 |
| „ „ 70 „ 30 „ . . . . . . . | 36 |
| Muntz metal, 60 copper, 40 zinc . . . . . . | 22 |
| Bronze, ordinary (extension, 1·2 to 4 per cent.) | 9·06 to 10·58 |

Delta metal: Copper $\frac{2}{3}$, zinc $\frac{1}{3}$, with 2 per cent. of iron :—

Cast in sand. Diam. ·611 in. Extension in 4 ins. 20·5 per cent.

| | | | |
|---|---|---|---|
| „ | 2 „ | 21·0 | „ |
| „ | 1 „ | 21·0 | „ |

Elastic limit of stress, per sq. in. 11·54 tons.
Maximum stress „ 23·89 „

| | |
|---|---|
| Gun metal, 12 copper, 1 tin . . . . . . . | 12·94 |
| „ 11 „ 1 „ . . . . . . . | 13·71 |
| „ 10 „ 1 „ . . . . . . . . | 14·73 |
| „ 9 „ 1 „ . . . . . . . | 17·00 |

Parsons' Manganese Bronze :—

| | No. 1, Annealed. | No. 2. |
|---|---|---|
| Elastic limit . . | 11 to 16 tons . | 16 to 19 tons. |
| Breaking weight . | 27 to 32 „ . . | 28 to 33 „ |
| Extension in 5 inches | 20 to 45 per cent. | 13 to 22 per cent. |

Manganese bronze: copper 88, tin 10, iron and manganese, 2 :—

| | | |
|---|---|---|
| Cast under pressure | (extension, 12·4 to 22 per cent.) | 31·9 to 35 |
| Rods rolled hot, annealed . . | ( „ 33·4 to 44·6 „ ) | 29 |
| Rods rolled hot, from rolls . | ( „ 23·3 to 26·5 „ ) | 31 |
| Rods rolled hot, finished cold | ( „ 11·6 „ ) | 39·6 |
| Plates rolled hot, annealed, with fibre . . | ( „ 28·8 to 47·8 „ ) | 30·10 |
| Plates rolled hot, annealed, across fibre . . . | ( „ 23·2 to 34·1 „ ) | 28·5 to 30·8 |
| Phosphor-bronze . | ( „ 3·6 to 33·4 . ) | 9·7 to 22·7 |

Bull's metal (extension in 8 inches, 16·4 per cent.),
Elastic limit 23·5 tons; breaking stress . . . . 32·82

Sterro-metal (Dr. Anderson) :—

| | |
|---|---|
| Copper 10, iron 10, zinc 80 . . . . . . | 3·17 |
| „ 60, „ 3, „ 39, tin, 1·5 . . . . | 24 |
| „ 60, „ 4, „ 44, „ 2 :— | |
| Cast in sand . . . . . . . . . . | 19·25 |
| Cast in iron, annealed . . . . . . . | 24·25 |
| Cast in iron, forged red hot . . . | 31 |

| | Tons per Sq. In. |
|---|---|
| Copper 60, iron 2, zinc 37, tin 1 | 34 |
| ,, 60, ,, 2, ,, 35, ,, 2 | 38 |
| ,, 55, ,, 1·77, ,, 42·36 ,, ·83 :— | |
| Cast | 27 |
| Forged red hot | 34 |
| Drawn cold | 38 |

**Ultimate Tensile Strength of Lead, Tin, Zinc, and Glass.**

| | Tons per Sq. In. |
|---|---|
| Lead, cast | ·81 |
| ,, sheet | ·86 |
| ,, pipe | 1·00 |
| Tin, cast | 2·11 |
| ,, banco | ·95 |
| ,, solder, soft (2 tin, 1 lead) | 3·35 |
| Zinc, cast | 1·34 |
| ,, sheet, with grain (London Zinc Mills) (extension, 14·2 per cent.) | 14·6 |
| Glass, flint, annealed | 1·07 |
| ,, green | 1·29 |
| ,, crown | 1·14 |
| ,, thin globes | 2·23 |

TABLE 195.—ULTIMATE TENSILE STRENGTH OF WIRES.
(Mr. Kirkaldy.)

Wires from $\frac{1}{13}$ to $\frac{1}{17}$ in. thick, except Phosphor bronze, $\frac{1}{8}$ in. thick.

| Wire. | Ultimate Tensile Strength per Square Inch. | | Extension, annealed. | Twists in Five Inches of Length. | |
|---|---|---|---|---|---|
| | Unannealed. | Annealed. | | Unannealed. | Annealed. |
| | Tons. | Tons. | Per cent. | Twists. | Twists. |
| Coke iron | 28·71 | 27·36 | 17 | 26 | 44 |
| Charcoal iron | 29·05 | 23·99 | 28 | 48 | 87 |
| Steel | 54·07 | 33·32 | 10·9 | * | 79 |
| Copper | 28·18 | 16·52 | 34·1 | 86·8 | 96 |
| Brass | 36·23 | 23·01 | 36·5 | 14·7 | 57 |
| Phosphor bronze, No. 1 | 71·21 | 26·27 | 46·6 | 13·3 | 66 |
| ,, No. 2 | 67·46 | 28·86 | 42·8 | 15·8 | 60 |
| ,, No. 3 | 62·12 | 24·15 | 44·9 | 17·3 | 53 |
| ,, No. 4 | 53·98 | 23·83 | 42·4 | 13 | 124 |

Silicium-bronze wire, No. 14, B. W. G., 29 tons per square in.

* Of the eight pieces of steel tested, 3 stood 40 to 45 turns, and 5 stood 1½ to 4 turns.

TABLE 196.—COMPARATIVE TENACITY OF METAL WIRES AT DIFFERENT TEMPERATURES.

The wires tested were about $\frac{1}{80}$th inch thick, except the iron wires, which were $\frac{1}{145}$th inch thick.

| | Tons per Square Inch. | | |
|---|---|---|---|
| | At 32° F. | At 212° F. | At 392° F. |
| Gold . . . . | 11·90 | 9·85 | 8·25 |
| Platinum . . . . . | 14·50 | 12·60 | 11·25 |
| Copper . . . . . | 18·20 | 15·90 | 13·75 |
| Silver . . . . . | 18·05 | 15·20 | 11·85 |
| Palladium . . . . | 23·30 | 20·75 | 17·85 |
| Iron . . . . . . | 131·75 | 124·70 | 134·5 |

The steel wire, $\frac{1}{10}$ inch thick, of the Brooklyn cable railway, was proved to an average ultimate tensile strength of 70·40 tons per square inch, with an extension of 7·3 per cent.

## RESISTANCE OF STONES AND OTHER BUILDING MATERIALS.

TABLE 197.—RESISTANCE OF STONES TO CRUSHING STRESS.

(Fairbairn.)

| Stone. | Cube. | Fractured at. | Crushed at. | Crushing Force. Per Sq. In. | Crushing Force. Per Sq. Ft. |
|---|---|---|---|---|---|
| | Inches. | Tons. | Tons. | Tons. | Tons. |
| Greywacke, Penmaenmaur | 2 | 18·1 | 30·2 | 7·5 | 1080 |
| Granite, Mount Sorrel . | 2 | 22·9 | 22·9 | 5·7 | 821 |
| Syenite ,, . . | 2 | 21·1 | 21·1 | 5·3 | 763 |
| Granite, Bonar, Inverary . | 1½ | 7·8 | 10·9 | 4·9 | 706 |
| Limestone . . . . . | 1½ | 7·7 | 8·6 | 3·8 | 547 |
| Sandstone . . . . | 1 | 1·4 | 1·6 | 1·6 | 230 |
| ,, . . . . . | 2 | 4·6 | 5·5 | 1·4 | 202 |
| Victoria Stone (granite and Portland cement, steeped in a solution of flint). . . . . . . . | | | | 3·71 | 534 |

TABLE 197.—RESISTANCE OF STONES TO CRUSHING STRESS (*continued*).

(L. Clark.)

RED SANDSTONE, average weight, 130·6 lbs. per cubic foot; 17 cubic feet per ton.

| Specimen. | Cube. | Crushing Load. | Load per Sq. In. | Load per Sq. Ft. |
|---|---|---|---|---|
| | Inches. | Tons. | Tons. | Tons. |
| No. 6. Quite dry, set between boards | 3 | 8·21 | ·91 | 131·0 |
| No. 7. Set in cement, moderately damp | 3 | 5·16 | ·57 | 82·1 |
| No. 8. Set in cement, very wet | 3 | 4·36 | ·48 | 69·1 |
| No. 9. Set in cement | 6 | 63·07 | 1·75 | 252·0 |
| Average | ... | ... | ·93 | 133·8 |

*Note.*—Gave way suddenly.

ANGLESEA LIMESTONE. Weight, 165·25 lbs. per cubic foot; 13½ cubic feet per ton.

| Specimen. | Cube. | Crushing Load. | Load per Sq. In. | Load per Sq. Ft. |
|---|---|---|---|---|
| No. 11. Set between boards | 3 | 26·58 | 2·95 | 424·8 |
| No. 12. " " began to crack at 25 tons | 3 | 32·30 | 3·60 | 518·4 |
| No. 13. Set between boards | 3 | 30·95 | 3·44 | 495·4 |
| No. 14. Three separate 1 inch cubes set between boards | ... | 9·37 | 3·12 | 449·3 |
| Average | ... | ... | 3·28 | 472·3 |

(Debauve.)

| | Weight per Cubic Foot. | Crushing Force per Sq. Inch. | Crushing Force per Sq. Foot. |
|---|---|---|---|
| | Pounds. | Tons. | Tons. |
| Granite: hard, fine grain | .. | 6·4 to 9·6 | 922 to 1382 |
| " " coarse grain | ... | 4·4 to 6·4 | 634 to 922 |
| " slowly decomposes in water: | | | |
| fine grain | ... | 3·8 to 5·7 | 547 to 821 |
| coarse grain | ... | 2·5 to 3·8 | 360 to 547 |
| Basalt | ... | 12·1 | 1742 |
| Lava | 112·3 | 2·7 | 389 |
| Porphyry | ... | 8·2 | 1181 |
| Jasper | ... | 11·7 | 1685 |
| Sandstone: hard | 131 to 156 | 2·2 to 4·9 | 317 to 706 |
| " semi-hard, or tender | 118·5 to 131 | ·51 to 1·9 | 73 to 274 |
| Limestone: for building | 87·4 to 174·7 | ·13 to 7·6 | 19 to 1094 |
| " hard | 137 to 175 | 1·4 to 7·6 | 202 to 1094 |
| " soft | 87·4 to 137 | ·51 to 1·4 | 73 to 202 |

### Table 198.—Resistance of Slates to Rupture. (Debauve.)

Pieces of Anjou slate, 10 inches square, resting by their four edges on a flat frame bearing, were loaded on a central space 4 inches square.

| Thickness. | | Breaking Load. | | Thickness. | | Breaking Load. | |
|---|---|---|---|---|---|---|---|
| Millims. | Inch. | Kilogrs. | Pounds. | Millims. | Inch. | Kilogrs. | Pounds. |
| 1 | ·0394 | 8 | 17·6 | 5 | ·1968 | 120 | 264 |
| 2 | ·0787 | 35 | 77 | 6 | ·2362 | 150 | 330 |
| 3 | ·1181 | 50 | 110 | 7 | ·2756 | 170 | 374 |
| 4 | ·1575 | 90 | 198 | | | | |

### Table 199.—Resistance of Bricks and Brickwork to Crushing Stress.

| Description. | Crushing Force per Square Inch. | Crushing Force per Square Foot. |
|---|---|---|
| | Tons. | Tons. |
| Red | ·358 | 51·6 |
| Yellow-faced, baked | ·446 | 64·2 |
| „ burned | ·643 | 92·6 |
| Gault clay, pressed | 1·111 | 160 |
| „ wire-cut | ·884 | 127·3 |
| „ perforated | 1·180 | 169·9 |
| Stock | 1·044 | 150·3 |
| Fareham red | 2·500 | 360 |
| Staffordshire blue, pressed with frogs | 3·100 | 446·4 |
| „ rough, without frogs | 3·275 | 471·6 |
| „ Hamblet's (Kirkcaldy) | 7·390 | 824 |
| Stourbridge fireclay | ·718 | 103·4 |
| Tividale blue | ·620 | 89·3 |
| Silex ferrine | 7·332 | 1056·2 |
| Vitrified granite, Candy's | 3·091 | 445·2 |
| Terra-cotta fire and sound proof (before cracking) | ·315 | 45·3 |
| Glass | 12·31 to 14·23 | 1773 |

TABLE 199.—RESISTANCE OF BRICKS AND BRICKWORK TO CRUSHING STRESS (*continued*).

| Cemented Brickwork. Best quality. | | | | | |
|---|---|---|---|---|---|
| | Cube. | Weight. | Crushing Load. | Load per Square Inch. | Load per Square Foot. |
| | Inches. | Pounds. | Tons. | Tons. | Tons. |
| No. 1, 9-inch cube set between deal boards | 9 | 54 | 19·94 | ·25 | 36·0 |
| No. 2, 9-inch cube in cement . . . | 9 | 53 | 22·15 | ·27 | 38·9 |
| No. 3, 9-inch cube in cement . . . | 9 | 52 | 16·42 | ·20 | 28·8 |
| No. 4, 9¼-inch cube in cement . . . | 9¼ | 55½ | 21·72 | ·27 | 38·9 |
| No. 5, 9-inch cube, between boards . . | 9 | 54¼ | 15·50 | ·19 | 27·4 |
| Average . . | . . . | . . . | . . . | ·23 | 34·0 |

*Note.*—Irregular cracks occurred a considerable time before the blocks gave way.

TABLE 200.—RESISTANCE OF PORTLAND CEMENT CONCRETE BLOCKS TO CRUSHING STRESS.

(Grant.)

| Portland Cement Concrete Blocks: 12 inch cubes compressed, 12 months old. | | | | | |
|---|---|---|---|---|---|
| | Cube. | Weight. | Crushing Load. | Load per Square Inch. | Load per Square Foot. |
| | Inches. | Pounds. | Tons. | Tons. | Tons. |
| 1 cement to 1 sand and gravel | 12 | ... | 170·5 | 1·18 | 170·5 |
| 1 " 3 " | 12 | ... | 115·5 | ·81 | 115·5 |
| 1 " 6 " | 12 | ... | 91·0 | ·63 | 91·0 |

TABLE 201.—ULTIMATE TENSILE STRENGTH OF STONES. (Debauve.)

| Stone. | Tensile Resistance per Square Inch. | Tensile Resistance per Square Foot. |
|---|---|---|
| | Tons. | Tons. |
| Basalt (Auvergne) | ·49 | 70·6 |
| Portland limestone | ·38 | 54·7 |
| Compact " | ·20 | 29 |
| Silicious " | ·14 | 20·2 |
| Oolitic " | ·09 | 13 |
| Brick of good quality | ·11 to ·13 | 16·8 to 18·7 |
| Bagneux rock (near Paris) | ·09 | 13 |
| Soft stone (le Vergelet) | ·045 | 6·5 |
| Stoneware pipes | 21lb. to 350lb. or ·15 ton. | 1·35 to 21·6 |

TABLE 202.—**Average Working Loads for Building Materials and Structures** (Austrian Association of Engineers).

(1) WEIGHT OF MATERIALS.

| Material. | | Lbs. per Cubic Foot. |
|---|---|---|
| TIMBER :— | | |
| Oak | | 50 |
| Pine | | 44 |
| Fir | | 44 |
| Red pine | | 41 |
| Pitch pine | | 41 |
| Larch | | 44 |
| METAL :— | | |
| Wrought iron (per cubic inch, ·28 lb.) | | 490 |
| Cast iron ( " ·27 lb.) | | 468 |
| Lead ( " ·40 lb.) | | 711 |
| Copper ( " ·32 lb.) | | 555 |
| Zinc ( " ·26 lb.) | | 449 |
| BRICK AND STONE :— | (Wet.) | (Dry.) |
| Hollow bricks | 87 | 75 |
| Ordinary " | 106 | 94 |
| Flemish " | 125 | 119 |
| Rubble Masonry | | 150 |
| Concrete | | 150 |
| Ashlar sandstone | | 150 to 156 |
| " limestone | | 162 to 169 |
| [illegible]ite | | 175 |

TABLE 202.—(1) WEIGHT OF MATERIALS (*continued*).

| Material. | Lbs. per Cubic Foot. |
|---|---|
| VARIOUS MATERIALS :— | |
| Broken stone | 87 |
| Fine dry sand | 77 |
| Coarse dry sand | 84 |
| Clay, loam, dry | 94 |
| „ wet | 119 |
| Lime mortar, cement mortar | 106 |
| Asphalte, pure | 69 |
| „ concrete | 100 |
| „ compressed | 113 |
| Gypsum | 72 |
| Window glass | 165 |

TABLE 202.—(2) WORKING STRESS.

| Material. | Tensile, per Square Inch. | Compressive, per Square Inch |
|---|---|---|
| | Tons. | Tons. |
| Wrought iron | 6·0 | 6·0 |
| Cast iron | 1·5 | 4·5 |
| Oak | ·60 | ·42 |
| Pine | ·54 | ·36 |
| Fir | ·42 | ·36 |
| Red pine | ·42 | ·33 |
| Larch | ·42 | ·33 |

TABLE 202.—(3) WORKING LOADS ON FOUNDATIONS.

| Foundation. | Tons per Square Foot. |
|---|---|
| Moist clay and sand (protected against lateral spreading) | 1·36 |
| Coarse sand and dry clay | 2·27 |
| Firm bedded broken stones on dry clay | 3·18 |
| Loose impermeable beds, with piling | 1·82 |
| „ „ „ and concrete | 2·73 |

TABLE 202.—(4) WORKING LOAD ON STONE WALLS AND COLUMNS.

| Material. | Thick Ashlar walls and single bed-stones and columns, where diameter is not less than half the height. | Block-in-course work and columns where diameter is from half to one-twelfth of height. | Columns where diameter is less than one-twelfth of height. |
|---|---|---|---|
| | Lbs. per Sq. Inch. | Lbs. per Sq. Inch. | Lbs. per Sq. Inch. |
| Granite, porphyry . . . . | 712 | 570 | 285 |
| Hard stone . . . . . . . | 356 | 285 | ... |
| Medium stone . . . . . | 214 | 142 | ... |
| Soft stone . . . . . . | 108 | ... | ... |

TABLE 202.—(5) WORKING LOADS ON BRICKWORK, MASONRY, &C.

| Description of Work. | Walls not less than 18 inches thick, and columns where diameter is not less than one-sixth of height. | Walls under 18 inches thick, and columns where diameter is from one-sixth to one-eighth of height. | Columns where diameter is from one-eighth to one-twelfth of height. |
|---|---|---|---|
| | Lbs. per Sq. Inch. | Lbs. per Sq. Inch. | Lbs. per Sq. Inch. |
| Brickwork in lime mortar . | 72 | 36 | ... |
| " cement " . . | 108 | 72 | ... |
| " Portland cement | 142 | 108 | 44 |
| Rubble masonry in lime mortar | 58 | ... | ... |
| " cement " . | 72 | ... | ... |
| Pressed bricks in " " . | 128 | 114 | 108 |
| " Portland cement | 172 | 142 | 114 |
| Flemish bricks in " . | 214 | 172 | 142 |
| Portland cement concrete . . | 100 | ... | ... |

TABLE 202.—(6) WORKING LOADS ON FLOORS, STAIRS, AND ROOFS.

| Location. | Lbs. per Square Foot. |
|---|---|
| Live loads on floors :— | |
| Attic floors | 30·8 |
| Dwelling-room floors | 51·2 |
| Libraries, dancing saloons, &c. | 71·7 |
| Stairs and passages | 82·0 |
| Business premises, workrooms, &c. | 92·2 |
| Hay and fruit lofts | 102·5 |
| Workshops and warehouses | 112·7 |
| Theatres, concert rooms, warehouses and workshops with heavy machinery or special loads | Loads specially adapted. |

Dead loads, snow and wind, on roofs—in lbs. per square yard on horizontal plane :—

| | Slope of Roof. | Dead Load. | Snow and Wind. | Total. |
|---|---|---|---|---|
| | | Lbs. | Lbs. | Lbs. |
| Single tile roof | 1 horizontal to 1·25 vertical | 27·7 | 25·6 | 53·3 |
| Double " | 1 to 1·25 | 33·8 | 25·6 | 59·4 |
| Single slate | 1 " 2·25 | 15·4 | 19·5 | 34·9 |
| Double " | 1 " 2·25 | 23·6 | 19·5 | 43·1 |
| Zinc or galvanised iron | 1 " 4 | 8·2 | 15·4 | 23·6 |
| Carton-Pierre | 1 " 4 | 8·2 | 15·4 | 23·6 |
| Sheet iron or iron purlins | 1 " 5 | 4·1 | 15·4 | 19·5 |

TABLE 202.—(7) SNOW AND WIND.

| | |
|---|---|
| Weight of snow on horizontal surface | allow 15·5 lbs. per sq. foot. |
| Wind pressure on surface at right angles to line of impact | " 24·6 " " |
| Do. do. in specially exposed positions | " 31·0 " " |

## RIVETED JOINTS IN BOILER PLATES.

The proportion by which maximum strength of riveted joints is attained, are given in Table 203, in terms of thickness of plates and diameter of rivets.

TABLE 203.—PROPORTIONS OF RIVETED JOINTS OF MAXIMUM STRENGTH.

| | |
|---|---|
| thickness of plates . . | = unity. |
| diameter of rivets . . . | = thickness of plate × 2. |
| pitch of rivets (single riveting) . . . . . | = thickness of plate × $5\frac{1}{3}$.<br>= diameter of rivets × $2\frac{2}{3}$. |
| pitch of rivets (double riveting) . . . . | = thickness of plates × 8.<br>= diameter of rivets × 4. |
| diagonal pitch (double riveting) . . . . | = longitudinal pitch × $\frac{3}{4}$.<br>= diameter of rivets × 3. |
| "spacing" (double riveting) | = longitudinal pitch × ·56, or $\frac{9}{16}$. |
| lap (single riveting) . | = thickness of plate × 6.<br>= diameter of rivets × 3. |
| lap (double riveting) . . | = thickness of plate × 10·48, or $10\frac{1}{2}$.<br>= diameter of rivets × 5·24, or $5\frac{1}{4}$. |

In conformity with the above proportions, the upper part of the following Table 204, shows the dimensions of rivet-joints in plates from $\frac{1}{8}$ inch to $\frac{11}{16}$ inch thick, for the last of which $1\frac{3}{8}$ inch rivets are provided. This is the largest size of rivets ordinarily used in boiler construction. For plates thicker than $\frac{11}{16}$ inch, the joints are to be made with $1\frac{3}{8}$ inch rivets, suitably pitched, for equal resistance of net section of plate and shearing resistance of rivets; and, therefore, for maximum strength when $1\frac{3}{8}$ inch rivets are used, as given in the lower part of the Table.

For boiler plates of iron and of steel $\frac{3}{8}$ inch in thickness, the breaking or ultimate strength of riveted joints in parts of that of the entire plate, are given in the Table 205. These relative values are deduced from the results of numerous experimental tests. The nominal diameter of rivets—not that of the rivet-holes—is adopted in calculation.

The percentage of breaking strength in the last two columns of Table 205 may be adopted for other thicknesses of plate up to $\frac{11}{16}$ inch, as in Table 204, upper part; except the values for single-riveted lap and singlewelt, which for thinner than $\frac{3}{8}$ inch plates are higher; and for thicker plates are lower. For plates thicker than $\frac{11}{16}$ inch, as in the lower part of Table 204, the breaking strengths may be taken as approximately in the proportion of the net sections of plate as percentages of the entire section. These are here subjoined in Table 206 :—

### TABLE 204.—DIMENSIONS OF RIVET JOINTS.
(Plates $\frac{1}{8}$ inch to $\frac{11}{16}$ inch thick).

| Thickness of Plates. | Diameter of Rivets. | Pitch of Rivets. Single-Riveting. | Pitch of Rivets. Double-Riveting. Longitudinal. | Pitch of Rivets. Double-Riveting. Diagonal. | Pitch of Rivets. Double-Riveting. Spacing.* | Lap. Single-Riveting. | Lap. Double-Riveting. |
|---|---|---|---|---|---|---|---|
| Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. |
| $\frac{1}{8}$ | $\frac{1}{4}$ | $\frac{2}{3}$ | 1 | $\frac{3}{4}$ | $\frac{9}{16}$ | $\frac{3}{4}$ | $1\frac{5}{16}$ |
| $\frac{3}{16}$ | $\frac{3}{8}$ | 1 | $1\frac{1}{2}$ | $1\frac{1}{8}$ | $\frac{27}{32}$ | $1\frac{1}{8}$ | 2 |
| $\frac{1}{4}$ | $\frac{1}{2}$ | $1\frac{1}{3}$ | 2 | $1\frac{1}{2}$ | $1\frac{1}{8}$ | $1\frac{1}{2}$ | $2\frac{5}{8}$ |
| $\frac{5}{16}$ | $\frac{5}{8}$ | $1\frac{2}{3}$ | $2\frac{1}{2}$ | $1\frac{7}{8}$ | $1\frac{13}{32}$ | $1\frac{7}{8}$ | $3\frac{1}{4}$ |
| $\frac{3}{8}$ | $\frac{3}{4}$ | 2 | 3 | $2\frac{1}{4}$ | $1\frac{11}{16}$ | $2\frac{1}{4}$ | $3\frac{15}{16}$ |
| $\frac{7}{16}$ | $\frac{7}{8}$ | $2\frac{1}{3}$ | $3\frac{1}{2}$ | $2\frac{5}{8}$ | 2 | $2\frac{5}{8}$ | $4\frac{5}{8}$ |
| $\frac{1}{2}$ | 1 | $2\frac{2}{3}$ | 4 | 3 | $2\frac{1}{4}$ | 3 | $5\frac{1}{4}$ |
| $\frac{9}{16}$ | $1\frac{1}{8}$ | 3 | $4\frac{1}{2}$ | $3\frac{3}{8}$ | $2\frac{1}{2}$ | $3\frac{3}{8}$ | $5\frac{7}{8}$ |
| $\frac{5}{8}$ | $1\frac{1}{4}$ | $3\frac{1}{3}$ | 5 | $3\frac{3}{4}$ | $2\frac{13}{16}$ | $3\frac{3}{4}$ | $6\frac{1}{2}$ |
| $\frac{11}{16}$ | $1\frac{3}{8}$ | $3\frac{2}{3}$ | $5\frac{1}{2}$ | $4\frac{1}{8}$ | $3\frac{1}{16}$ | $4\frac{1}{8}$ | $7\frac{1}{4}$ |
| $\frac{3}{4}$ | $1\frac{3}{8}$ | 3·475 | 5·156 | 3·867 | 2·900 | $4\frac{1}{8}$ | $7\frac{1}{4}$ |
| $\frac{13}{16}$ | $1\frac{3}{8}$ | 3·318 | 4·866 | 3·650 | 2·737 | $4\frac{1}{8}$ | $7\frac{1}{4}$ |
| $\frac{7}{8}$ | $1\frac{3}{8}$ | 3·179 | 4·616 | 3·462 | 2·597 | $4\frac{1}{8}$ | $7\frac{1}{4}$ |
| $\frac{15}{16}$ | $1\frac{3}{8}$ | 3·059 | 4·401 | 3·301 | 2·475 | $4\frac{1}{8}$ | $7\frac{1}{4}$ |
| 1 | $1\frac{3}{8}$ | 2·953 | 4·212 | 3·159 | 2·370 | $4\frac{1}{8}$ | $7\frac{1}{4}$ |
| $1\frac{1}{16}$ | $1\frac{3}{8}$ | 2·860 | 4·045 | 3·034 | 2·275 | $4\frac{1}{8}$ | $7\frac{1}{4}$ |
| $1\frac{1}{8}$ | $1\frac{3}{8}$ | 2·778 | 3·895 | 2·921 | 2·191 | $4\frac{1}{8}$ | $7\frac{1}{4}$ |

### TABLE 205.—ULTIMATE RELATIVE STRENGTH OF RIVETED JOINTS IN $\frac{3}{8}$-INCH BOILER PLATES.

| $\frac{3}{8}$-inch Plate Joint. | Thickness of Plate. | Rivets. Diameter. | Rivets. Pitch longitudinally. | Nominal net section of plate in parts of that of whole plate. | Breaking Strength in Parts of that of Whole Plate. Iron. | Breaking Strength in Parts of that of Whole Plate. Steel. |
|---|---|---|---|---|---|---|
| | Inch. | Inch. | Inches. | Per cent. | Per cent. | Per cent. |
| Single-riveted lap . | $\frac{3}{8}$ | $\frac{3}{4}$ | 2 | 62·5 | 56 | 60 |
| ,, single welt | $\frac{3}{8}$ | $\frac{3}{4}$ | 2 | 62·5 | 50 | 58 |
| ,, double welt | $\frac{3}{8}$ | $\frac{3}{4}$ | 2 | 62·5 | 60 | 65 |
| Double-riveted lap . | $\frac{3}{8}$ | $\frac{3}{4}$ | 3 | 75 | 70 | 80 |
| ,, single welt | $\frac{3}{8}$ | $\frac{3}{4}$ | 3 | 75 | 65 | 78 |
| ,, double welt | $\frac{3}{8}$ | $\frac{3}{4}$ | 3 | 75 | 72 | 80 |

* *Note.*—"Spacing" is the pitch of the longitudinal centre-lines of rivets in double-riveted joints.

TABLE 206.—NET PLATE SECTION OF PLATES $\frac{3}{4}$ INCH AND UPWARDS IN THICKNESS.

| Thickness of Plate. | Diameter of Rivets. | Net Plate Section in parts of Whole Section. Single Riveting. | Net Plate Section in parts of Whole Section. Double riveting. |
|---|---|---|---|
| Inches. | Inches. | Per cent. | Per cent. |
| $\frac{3}{4}$ | $1\frac{3}{8}$ | 60·4 | 73·5 |
| $\frac{13}{16}$ | $1\frac{3}{8}$ | 58·6 | 71·7 |
| $\frac{7}{8}$ | $1\frac{3}{8}$ | 56·8 | 70·2 |
| $\frac{15}{16}$ | $1\frac{3}{8}$ | 55·0 | 68·8 |
| 1 | $1\frac{3}{8}$ | 53·4 | 67·4 |
| $1\frac{1}{16}$ | $1\frac{3}{8}$ | 51·9 | 66·0 |
| $1\frac{1}{8}$ | $1\frac{3}{8}$ | 50·5 | 64·7 |

The most suitable pitches for given diameters of rivets, or, on the contrary, the most suitable diameters of rivets for given pitches, in order to form joints of equal resistance, may be calculated by means of the following formulæ (92) and (93), as, of course, pitches and diameters may be adopted other than those which are above-recommended :—

single riveted lap joint :—

$$p = \cdot835\frac{d^2}{t} + d \qquad (92)$$

$$d = \sqrt{1\cdot20\,t\,p + \cdot36\,t^2} - \cdot60\,t \qquad (93)$$

These formulæ are applicable also for single-riveted single-welt and double-welt joints.

double riveted lap joints :—

$$p = 1\cdot5\frac{d^2}{t} + d \qquad (94)$$

$$d = \sqrt{\frac{2}{3}\,t\,p + \frac{t^2}{9}} - \frac{t}{3} \qquad (95)$$

These formulæ are applicable also for double-riveted single-welt and double-welt joints.

## BOILER SHELLS.

The bursting strength per square inch of a cylindrical boiler shell is twice as much longitudinally, that is to say, parallel to the axis, as it is transversely.

Bursting pressure $\quad p = \dfrac{4480ts}{d} \qquad (96)$

Thickness of plates $\quad t = \dfrac{dp}{4480s} \qquad (97)$

Ultimate tensile strength of plates $s=\frac{dp}{4480t}$ . . . (98)

$d$ = internal diameter, in inches.
$t$ = thickness of plate, in inches.
$s$ = ultimate tensile strength of plate, in tons per square inch.
$p$ = effective steam pressure, in pounds per square inch.

When the shell is constructed with riveted joints, the tensile strength $s$ is to be reduced in the ratio of the ultimate strength of the whole plate to that of the joint.

The resistance of a hollow sphere to internal pressure is twice as much as that of a tube of equal diameter and equal thickness.

### Strength of Ends of Cylindrical Steam Boilers.

For a flat end-plate forming the termination of a cylindrical shell, unstayed or unsupported except at the circumference, the ultimate elastic deflection under internal pressure is given by the formulæ :—

$$\delta=\frac{\text{radius}}{22}=\frac{r}{22} \quad . \quad . \quad . \quad . \quad (99)$$

$$\delta=\frac{\text{diameter}}{44}=\frac{d}{44} \quad . \quad . \quad . \quad . \quad (100)$$

$\delta$ = deflection at the centre in inches.
$r$ = radius of the cylinder, in inches.
$d$ = diameter of the cylinder in inches.

The relative internal pressure and stress in the end-plate strained to the elastic limit, are given by this formula :—

$$p=\frac{815ts}{d} \quad . \quad . \quad . \quad . \quad (101)$$

$p$ = effective internal pressure, in lbs. per square inch.
$t$ = thickness of end-plate, in inches.
$s$ = tensile stress in end-plate, in tons per square inch at the elastic limit.

This formula is applicable for steel plates, as for iron plates, taking the elastic limit to be the same for both metals, namely, $\frac{1}{1000}$th of the length. The elastic strength, $s$, is, for iron, 12 tons ; for steel 14 tons per square inch. Substituting these values in formula (101), the final formulæ are derived for the elastic strength of circular flat end-plates of iron and of steel, of uniform thickness, fastened at the circumference, exposed to bulging pressure uniformly distributed :—

for iron, $$p = 10{,}000\,\frac{t}{d} \quad . \quad . \quad . \quad . \quad (102)$$

for steel, $$p = 11{,}500\,\frac{t}{d} \quad . \quad . \quad . \quad . \quad (103)$$

$p$ = bulging pressure, in lbs. per square inch.
$t$ = thickness of the plate, in inches.
$d$ = diameter of the plate, in inches, measured to the circular line of junction.

*Flat Cast-iron Ends.*

The elastic strength of flat cast-iron ends, adopting an extension of $\frac{1}{1000}$th part of the length, as for iron and steel, corresponding to a tensile stress of 5 tons per square inch, is expressed by the formulæ :—

$$\delta = \frac{d}{44} \quad . \quad . \quad . \quad . \quad . \quad (10\ )$$

$$p = 4000\,\frac{t}{d} \quad . \quad . \quad . \quad . \quad . \quad (105)$$

$\delta$ = deflection at centre, within the elastic limit, in inches.
$d$ = diameter of the line of fastening, in inches.
$t$ = thickness of the plate in inches.
$p$ = elastic bulging pressure, in lbs. per square inch, uniformly distributed.

For cast-iron of stronger quality, the co-efficient in formula (105) is to be increased in proportion.

*Segmental Ends.*

The relation of the internal pressure and stress in a segmental or spherical end of a cylindrical shell, is given by the formula :—

$$p = \frac{8960ts}{\frac{r^2}{v} + v} \quad . \quad . \quad . \quad . \quad . \quad (106)$$

$p$ = internal pressure, in lbs. per square inch.
$t$ = thickness of segmental end, in inches.
$s$ = tensile stress in the plate, in tons per square inch.
$r$ = radius of the circular junction, in inches.
$v$ = versed sine or rise of the segment, in inches.

Substituting for the values of $s$: 12 tons for wrought iron,

14 tons for steel, and 5 tons for cast iron, the formula becomes :—

Wrought iron, $$p=\frac{108{,}000t}{\frac{r^2}{v}+v} \qquad (107)$$

Steel, $$p=\frac{125{,}000t}{\frac{r^2}{v}+v} \qquad (108)$$

Cast-iron, $$p=\frac{45{,}000t}{\frac{r^2}{v}+v} \qquad (109)$$

The versed sine or rise at the centre of a spherical segment having the same elastic strength as the body of the cylinder, measured by the internal pressure, is, say, one-fourth of the radius of the end of the cylinder, or one-eighth of its diameter.

*Strength of Stayed Flat Plates of Steam Boilers.*

The relative internal pressure and stress in a flat-stayed plate, strained to the elastic limit, are given by the formula :—

$$p=\frac{407ts}{d} \qquad (110)$$

$p$ = internal pressure in lbs. per square inch.
$t$ = thickness of the plate in inches.
$d$ = clear distance apart between the bolts in rectangular arrangement.
$s$ = tensile stress in the plate, in tons per square inch, at the elastic limit.

When the pitches of the staybolts, vertically and transversely, are not equal to each other, the greater clear distance is to be taken for calculation.

Reducing the above formula (110) for iron and for steel plates, of which the values of $s$ are taken as 12 tons and 14 tons respectively, and also inverting the formulæ to find the thickness of plate, and the clear distance apart of the staybolts, the following formulæ are obtained :—

| For Iron. | For steel. | |
|---|---|---|
| $p=5{,}000\frac{t}{d}$ | $p=5{,}700\frac{t}{d}$ | (111) |
| $t=\frac{pd}{5{,}000}$ | $t=\frac{pd}{5{,}700}$ | (112) |
| $d=\frac{5{,}000t}{p}$ | $d=\frac{5{,}700t}{p}$ | (113) |

The proper diameter of screwed stay bolts, at the base of the thread, strained to the elastic limit, simultaneously with the plate, is given by formula :—

$$d' = \cdot 0024\sqrt{\frac{P\,P'\,p}{s}} \quad . \quad . \quad . \quad (114)$$

$d$ = diameter of staybolts, at base of thread.
P = pitch of staybolts between centres, longitudinally.
P′ = „ „ „ transversely.
$p$ = maximum effective elastic pressure, in lbs. per square inch, on the plate.
$s$ = elastic tensile strength of staybolts, in tons per square inch.

For bolts of iron, steel, and copper, having respectively 12 tons, 14 tons, and 8 tons, elastic tensile strength per square inch, the special formulæ for the proper diameter of the staybolts, at the base of the thread, are :—

$$\text{Iron } d' = \cdot 00069\sqrt{P\,P'\,p}\,; \text{ or } d' = \frac{\text{When } P'=P}{\cdot 00069} P\sqrt{p} \quad (115)$$

$$\text{Steel } d' = \cdot 00064\sqrt{P\,P'\,p}\,; \text{ or } d' = \cdot 00064\, P\sqrt{p} \quad . \quad (116)$$

$$\text{Copper } d' = \cdot 00084\sqrt{P\,P'\,p}\,; \text{ or } d' = \cdot 00084\, P\sqrt{p} \quad . \quad (117)$$

*Collapsing Resistance of Furnace-tubes.*

Plain furnace-tubes of Lancashire and Cornish steam-boilers, without stiffening joints, have the maximum resistance to collapsing pressure under steam, according to the formula :—

$$p = \frac{200{,}000\, t^2}{d^{1 \cdot 75}} \quad . \quad . \quad . \quad . \quad (118)$$

$p$ = collapsing pressure, in lbs. per square inch.
$t$ = thickness of the plates of the furnace-tube in inches.
$d$ = internal diameter of the furnace tube in inches.

This formula is applicable to furnace-tubes of lengths of over 9 feet. Tubes of shorter length derive natural assistance from the end fastenings.

*Segmental Crowns of Furnaces.*

The elastic resistance of a segmental crown of a cylindrical ace, to collapsing pressure externally may be formulated

in the same terms as the resistance to bursting pressure internally, here repeated :—

$$p=\frac{8960\,t\,s}{\frac{r^2}{r}+v} \quad . \quad . \quad . \quad . \quad . \quad (119)$$

$t$ = thickness of plate, in inches.
$r$ = radius of circular junction, in inches.
$v$ = versed sine, or rise of segment, in inches.
$p$ = external collapsing pressure, in lbs. per square inch.
$s$ = compressive stress in the segment, in tons per square inch.

For the application of this formula, it is assumed that the spherical segment is perfectly formed. A segment of which the rise is one-eighth of the diameter of the cylindrical base is equally stressed with the base, under equal external pressure per square inch.

When the spherical segment is a hemisphere, made of plates equal in thickness to those of the cylinder, it is stressed to only half the extent per square inch to which the cylinder is stressed.

**Hydraulic, Steam, and other Hollow Cylinders.**

The resistance of, say, a hydraulic ram, to bursting pressure is unequally distributed over the transverse section of the ram, being a maximum at the interior surface, diminishing radially to a minimum at the outer surface. The inequality of active resistance arises from the stretching of the material exposed to pressure, up to and beyond the elastic limit.

The formulas for resistance, in their most general form, are as follows :—

$$p=s\times \text{hyp log. R.} \quad . \quad . \quad . \quad . \quad (120)$$

$$s=\frac{p}{\text{hyp log. R.}} \quad . \quad . \quad . \quad . \quad . \quad (121)$$

$$\text{hyp log. R}=\frac{p}{s} \quad . \quad . \quad . \quad . \quad . \quad (122)$$

$$d'=d\times \text{R} \quad . \quad . \quad . \quad . \quad . \quad . \quad (123)$$

$$t=\frac{d\,(\text{R}-1)}{2} \quad . \quad . \quad . \quad . \quad . \quad (124)$$

$d$ = inside diameter, in inches.
$d'$ = outside diameter, in inches.
$p$ = internal pressure in tons per square inch.
$s$ = maximum tensile stress, in tons per square inch.
R = ratio of outside diameter to inside diameter, or $\frac{d'}{d}$

*Note.*—The pressure and stress may be expressed in hundredweights or in pounds.

In cases where the internal tensional stress on the material exceeds the elastic limit, the formulas are to be taken as only approximate. But it is believed that in such cases they are substantially correct for practical purposes. They are taken as correct for maximum tensional stress not exceeding the elastic limit.

The average tensional stress on the metal is equal to $\frac{p\,d}{d' - d}$.

That is to say, it is equal in tons per square inch to the product of the inside diameter by the internal pressure in tons per square inch, divided by the difference of the inside and outside diameters.

*Example.*—To find the bursting pressure of a cast-iron cylinder 8 inches in diameter inside, and 25 inches outside, the ultimate tensile strength of the metal being 7 tons per square inch. The ratio of the diameters is $(25 \div 8 =)$ 3·12, of which the hyperbolic logarithm is 1·1378. By formula (120), the bursting pressure is $(7 \times 1{\cdot}1378 =)$ 7·96 tons per square inch. The average stress over the whole sectional area of the metal is equal to $(8 \times 7{\cdot}96) \div (25 - 8) = 3{\cdot}75$ tons per square inch of section of metal.

2nd *Example.*—To find the bursting pressure of a hydraulic tube $1\frac{7}{8}$ inches in bore, $\frac{5}{16}$ inch thick; the direct ultimate tensile strength being 22 tons per square inch. The ratio of the outside and inside diameters is $(2\frac{1}{2} \div 1\frac{7}{8} =)$ 1·33, the hyperbolic logarithm of which is ·2852. By formula (120), the bursting pressure is 6·27 tons, or 14,045 pounds per square inch. The tube had been proved to a pressure of 11,000 pounds without failure.

In cases where the diameter is considerable in relation to the thickness, the transverse resistance to bursting pressure is taken as equal to the direct tensile strength per square inch of sectional area, according to the common rules already given.

## WIRE ROPES AND HEMP ROPES.

The comprehensive Tables 207 to 211—of the weight and strength of wire ropes manufactured by Messrs. Dixon & Corbitt and R. S. Newall & Co.—comprise qualities varying from annealed iron having an ultimate tensile strength of 25 tons per square inch, and charcoal iron wire of 34 tons per

square inch, to special or extra plough steel wire of 150 tons. The "patent steel" is crucible steel or open hearth steel hardened and tempered by a special process.

The breaking strengths have been carefully ascertained. They are based on the most common system of construction:—round ropes of 6 strands of 7 wires each, or 6 strands of 6 wires each. In the first there are 6 wires over a central wire; in the second, 6 wires over a hemp core. With such proportions, the cylindrical form is best maintained, and splicing is most readily effected. But ropes are made with from 3 to 12 strands. Wires vary from ·010 inch to ·212 inch in diameter for 6-strand ropes of 7 wires in each strand. But conductor or guide-ropes of 7 wires forming a strand have been made of $\frac{5}{8}$ inch rods.

Tables 212 and 213 give the sizes and strength of hemp ropes by Messrs. Dixon & Corbitt and R. S. Newall & Co. For the dimensions of cotton ropes, the same firm assume that cotton is equal in strength to hemp; and for coir ropes, that coir, or cocoa-fibre, is of half the strength.

For vertical winding at a high speed, they adopt one-tenth of the breaking stress as a safe working load. But the load may, with suitable working conditions, be increased to a value of one-eighth. The gross weight hanging over the pulley is taken as the working load.

For hauling, the working load is usually taken by them at one-sixth of the breaking stress; and the following form of calculation for determining the proper size of rope, has been found by experience to be satisfactory:—Take an inclined plane, say, 800 yards in length; load, 20 tons; maximum inclination of road, 7 degrees, or 1 in 8·14.

*Calculation for Resistance.*

| | cwts. | qrs. | lbs. |
|---|---|---|---|
| Gravity of load, 20 tons × 272·93 lbs. per ton . | 49 | 0 | 16 |
| Friction of load, 20 tons × 20 lbs. per ton . . | 3 | 2 | 8 |
| Gravity of rope, 800 yards, at 2 lbs. per yard, = 1600 lbs. ÷ 8·14 . . . . . . . . . | 1 | 3 | 1 |
| Friction of rope, 1600 lbs. ÷ 20 . . . . . . | 0 | 2 | 24 |
| Total working stress or load . . . . . | 55 | 0 | 21 |

## Table 207.—Round Wire Ropes: Weight

| Sizes. Diameter. | Sizes. Circumference. | Weights per Fathom. 6 Strands. 7 Wires. | Weights per Fathom. 6 Strands. 6 Wires. | Charcoal Iron. Breaking Strain. | Charcoal Iron. Working Load. Pit. | Charcoal Iron. Working Load. Incline. | Bessemer Steel, or Ingot Iron. Breaking Strain. | Bessemer Steel, or Ingot Iron. Working Load. Pit. | Bessemer Steel, or Ingot Iron. Working Load. Incline. | Phosphor Bronze. Breaking Strain. | Phosphor Bronze. Working Load. Pit. | Phosphor Bronze. Working Load. Incline. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ins. | Ins. | Lbs. | Lbs. | Tons. | Cwts. | Cwts. | Tons. | Cwts. | Cwts. | Tons. | Cwts. | Cwts. |
| $\frac{11}{32}$ | $1\frac{1}{8}$ | 1·2 | 1·1 | 1·9 | 3 | 5 | 2·2 | 4 | 7 | 2·2 | 4 | 7 |
| $\frac{3}{8}$ | $1\frac{1}{4}$ | 1·5 | 1·3 | 2·2 | 4 | 7 | 2·6 | 5 | 8 | 2·6 | 5 | 8 |
| $\frac{13}{32}$ | $1\frac{3}{8}$ | 1·8 | 1·6 | 2·7 | 5 | 9 | 3·2 | 6 | 10 | 3·2 | 6 | 10 |
| $\frac{15}{32}$ | $1\frac{1}{2}$ | 2·1 | 1·9 | 3·3 | 6 | 11 | 3·8 | 7 | 12 | 3·8 | 7 | 12 |
| $\frac{1}{2}$ | $1\frac{5}{8}$ | 2·5 | 2·3 | 4·0 | 8 | 13 | 4·6 | 9 | 15 | 4·6 | 9 | 15 |
| $\frac{9}{16}$ | $1\frac{3}{4}$ | 2·9 | 2·6 | 4·5 | 9 | 15 | 5·2 | 10 | 17 | 5·2 | 10 | 17 |
| $\frac{19}{32}$ | $1\frac{7}{8}$ | 3·3 | 3·0 | 5·2 | 10 | 17 | 6·0 | 12 | 20 | 6·0 | 12 | 20 |
| $\frac{5}{8}$ | 2 | 3·8 | 3·5 | 6·2 | 12 | 20 | 7·0 | 14 | 23 | 7·0 | 14 | 23 |
| $\frac{11}{16}$ | $2\frac{1}{8}$ | 4·3 | 4·0 | 7·0 | 14 | 23 | 8·0 | 16 | 26 | 8·0 | 16 | 26 |
| $\frac{23}{32}$ | $2\frac{1}{4}$ | 4·8 | 4·4 | 7·7 | 15 | 25 | 8·8 | 18 | 29 | 8·8 | 18 | 29 |
| $\frac{3}{4}$ | $2\frac{3}{8}$ | 5·3 | 4·9 | 8·5 | 17 | 28 | 9·8 | 20 | 32 | 9·8 | 20 | 32 |
| $\frac{25}{32}$ | $2\frac{1}{2}$ | 5·9 | 5·5 | 9·6 | 19 | 32 | 11·0 | 22 | 36 | 11·0 | 22 | 36 |
| $\frac{27}{32}$ | $2\frac{5}{8}$ | 6·6 | 6·0 | 10·5 | 21 | 35 | 12·0 | 24 | 40 | 12·0 | 24 | 40 |
| $\frac{7}{8}$ | $2\frac{3}{4}$ | 7·1 | 6·6 | 11·5 | 23 | 38 | 13·2 | 26 | 44 | 13·2 | 26 | 44 |
| $\frac{29}{32}$ | $2\frac{7}{8}$ | 7·8 | 7·2 | 12·6 | 25 | 42 | 14·4 | 28 | 48 | 14·4 | 28 | 48 |
| $\frac{15}{16}$ | 3 | 8·5 | 7·8 | 13·6 | 27 | 45 | 15·6 | 31 | 52 | 15·6 | 31 | 52 |
| 1 | $3\frac{1}{8}$ | 9·2 | 8·5 | 14·8 | 29 | 49 | 17·0 | 34 | 56 | 17·0 | 34 | 56 |
| $1\frac{1}{32}$ | $3\frac{1}{4}$ | 9·9 | 9·1 | 15·9 | 31 | 53 | 18·2 | 36 | 60 | 18·2 | 36 | 60 |
| $1\frac{1}{16}$ | $3\frac{3}{8}$ | 10·7 | 9·9 | 17·5 | 34 | 57 | 19·8 | 39 | 66 | 19·8 | 39 | 66 |
| $1\frac{1}{8}$ | $3\frac{1}{2}$ | 11·5 | 10·6 | 18·5 | 37 | 61 | 21·2 | 42 | 70 | 21·2 | 42 | 70 |
| $1\frac{5}{32}$ | $3\frac{5}{8}$ | 12·3 | 11·4 | 19·9 | 39 | 66 | 22·8 | 45 | 76 | 22·8 | 45 | 76 |
| $1\frac{3}{16}$ | $3\frac{3}{4}$ | 13·2 | 12·2 | 21·3 | ·42 | 71 | 24·4 | 48 | 81 | 24·4 | 48 | 81 |
| $1\frac{7}{32}$ | $3\frac{7}{8}$ | 14·1 | 13·0 | 22·7 | 45 | 75 | 26·0 | 52 | 86 | 26·0 | 52 | 86 |
| $1\frac{1}{4}$ | 4 | 15·0 | 13·9 | 24·3 | 48 | 81 | 27·8 | 55 | 92 | 27·8 | 55 | 92 |
| $1\frac{5}{16}$ | $4\frac{1}{8}$ | 16·0 | 14·8 | 25·9 | 51 | 85 | 29·6 | 59 | 98 | 29·6 | 59 | 98 |
| $1\frac{11}{32}$ | $4\frac{1}{4}$ | 17·0 | 15·7 | 27·4 | 54 | 91 | 31·4 | 62 | 104 | 31·4 | 62 | 104 |
| $1\frac{3}{8}$ | $4\frac{3}{8}$ | 18·0 | 16·6 | 29·0 | 58 | 96 | 33·2 | 66 | 110 | 33·2 | 66 | 110 |
| $1\frac{7}{16}$ | $4\frac{1}{2}$ | 19·0 | 17·6 | 30·8 | 61 | 102 | 35·2 | 70 | 117 | 35·2 | 70 | 117 |
| $1\frac{1}{2}$ | $4\frac{3}{4}$ | 21·2 | 19·6 | 34·3 | 68 | 114 | 39·2 | 78 | 130 | 39·2 | 78 | 130 |
| $1\frac{17}{32}$ | $4\frac{7}{8}$ | 22·0 | 20·6 | 36·0 | 72 | 126 | 41·2 | 82 | 137 | 41·2 | 82 | 137 |
| $1\frac{19}{32}$ | 5 | 23·5 | 21·7 | 37·9 | 75 | 126 | 43·4 | 86 | 144 | 43·4 | 86 | 144 |
| $1\frac{11}{16}$ | $5\frac{1}{4}$ | 26·0 | 24·0 | 42·0 | 84 | 140 | 48·0 | 96 | 160 | 48·0 | 96 | 160 |
| $1\frac{3}{4}$ | $5\frac{1}{2}$ | 28·5 | 26·3 | 45·5 | 91 | 151 | 52·6 | 105 | 175 | 52·6 | 105 | 175 |
| $1\frac{13}{16}$ | $5\frac{3}{4}$ | 31·1 | 28·7 | 50·2 | 100 | 167 | 57·4 | 114 | 191 | 57·4 | 114 | 191 |
| $1\frac{29}{32}$ | 6 | 34·0 | 31·3 | 54·7 | 109 | 182 | 62·6 | 125 | 208 | 62·6 | 125 | 208 |

AND STRENGTH (Dixon & Corbitt).

| Crucible Steel. | | | Patent Steel. | | | Plough Steel. | | | Extra Plough Steel. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Breaking Strain. | Working Load. | | Breaking Strain. | Working Load. | | Breaking Strain. | Working Load. | | Breaking Strain. | Working Load. | |
| | Pit. | Incline. | | Pit. | Incline. | | Pit. | Incline. | | Pit. | Incline. |
| Tons. | Cwts. | Cwts. | Tons. | Cwts. | Cwts. | Tons. | Cwts. | Cwts. | Tons. | Cwts. | Cwts. |
| 2·7 | 5 | 9 | 3·4 | 6 | 11 | 4·2 | 8 | 14 | 4·9 | 10 | 16 |
| 3·2 | 6 | 10 | 4·0 | 8 | 13 | 4·9 | 10 | 16 | 5·8 | 12 | 19 |
| 4·0 | 8 | 13 | 5·0 | 10 | 16 | 6·1 | 12 | 20 | 7·2 | 14 | 24 |
| 4·7 | 9 | 15 | 5·9 | 12 | 20 | 7·2 | 14 | 24 | 8·5 | 17 | 28 |
| 5·7 | 11 | 18 | 7·2 | 14 | 24 | 8·7 | 17 | 29 | 10·3 | 21 | 34 |
| 6·5 | 13 | 21 | 8·0 | 16 | 26 | 9·9 | 20 | 33 | 11·7 | 24 | 39 |
| 7·5 | 15 | 25 | 9·4 | 19 | 31 | 11·4 | 23 | 37 | 13·5 | 27 | 45 |
| 8·7 | 17 | 29 | 10·9 | 22 | 36 | 13·3 | 26 | 44 | 15·7 | 31 | 52 |
| 10·0 | 20 | 33 | 12·6 | 25 | 42 | 15·3 | 30 | 50 | 18·0 | 36 | 60 |
| 11·0 | 22 | 36 | 13·8 | 28 | 46 | 16·8 | 33 | 55 | 19·8 | 40 | 66 |
| 12·2 | 24 | 40 | 15·3 | 31 | 51 | 18·7 | 37 | 62 | 22·0 | 44 | 73 |
| 13·7 | 27 | 45 | 17·2 | 35 | 57 | 21·0 | 42 | 70 | 24·7 | 49 | 82 |
| 15·0 | 30 | 50 | 19·9 | 39 | 66 | 22·9 | 46 | 76 | 27·0 | 54 | 90 |
| 16·5 | 33 | 55 | 20·8 | 43 | 69 | 25·1 | 50 | 84 | 29·7 | 59 | 99 |
| 18·0 | 36 | 60 | 22·6 | 45 | 75 | 27·5 | 55 | 91 | 32·4 | 64 | 108 |
| 19·5 | 39 | 65 | 24·5 | 49 | 81 | 29·8 | 59 | 99 | 35·1 | 70 | 117 |
| 21·2 | 42 | 70 | 26·7 | 53 | 89 | 32·5 | 65 | 108 | 38·2 | 76 | 127 |
| 22·7 | 45 | 75 | 28·6 | 57 | 95 | 34·8 | 69 | 116 | 40·0 | 82 | 136 |
| 24·7 | 49 | 82 | 31·1 | 62 | 103 | 37·8 | 75 | 126 | 44·5 | 89 | 148 |
| 26·5 | 53 | 88 | 33·3 | 67 | 111 | 40·5 | 80 | 135 | 47·7 | 95 | 159 |
| 28·5 | 57 | 94 | 35·9 | 72 | 119 | 43·6 | 87 | 145 | 51·3 | 102 | 171 |
| 30·5 | 61 | 101 | 38·4 | 77 | 128 | 46·6 | 93 | 155 | 54·0 | 108 | 180 |
| 32·5 | 65 | 108 | 40·9 | 82 | 136 | 49·7 | 99 | 165 | 58·5 | 117 | 195 |
| 34·7 | 69 | 115 | 43·7 | 87 | 145 | 53·1 | 106 | 177 | 62·5 | 125 | 208 |
| 37·0 | 74 | 123 | 46·6 | 93 | 155 | 56·6 | 113 | 188 | 66·6 | 133 | 222 |
| 39·2 | 78 | 130 | 49·4 | 99 | 164 | 60·0 | 120 | 200 | 70·6 | 141 | 235 |
| 41·5 | 83 | 138 | 52·2 | 105 | 174 | 63·4 | 127 | 211 | 74·7 | 149 | 249 |
| 44·0 | 88 | 146 | 55·4 | 111 | 184 | 67·3 | 134 | 224 | 79·2 | 158 | 264 |
| 49·0 | 98 | 163 | 61·7 | 123 | 205 | 74·9 | 150 | 249 | 88·2 | 176 | 294 |
| 51·5 | 103 | 171 | 64·8 | 130 | 216 | 78·8 | 157 | 262 | 92·7 | 185 | 309 |
| 54·2 | 108 | 180 | 68·3 | 137 | 227 | 83·0 | 166 | 276 | 97·6 | 195 | 325 |
| 60·0 | 120 | 200 | 75·6 | 151 | 252 | 91·8 | 183 | 306 | 108·0 | 216 | 360 |
| 65·7 | 131 | 219 | 82·8 | 175 | 275 | 100·5 | 201 | 335 | 118·3 | 238 | 394 |
| 71·7 | 143 | 239 | 90·3 | 180 | 301 | 109·7 | 219 | 365 | 129·1 | 258 | 430 |
| 78·2 | 156 | 260 | 98·5 | 197 | 328 | 119·7 | 239 | 399 | 140·8 | 281 | 469 |

The next higher working load for Extra Plough Steel Ropes on inclines, in Table 207, is 60 cwts., for which a $2\frac{1}{8}$-inch rope is required.

The subjoined table shows the inclination of inclined ways, in inches per yard, and the length for a rise of 1, corresponding to a given number of degrees of inclination; together with the resistance of gravity for each incline.

### Table 208.—Inclination and Resistance of Inclined Ways.

(Dixon & Corbitt.)

| Inclination. | Inclination in Inches per Yard. | Inclination. | Resistance of Gravity due to Incline. | Inclination. | Inclination in Inches per Yard. | Inclination. | Resistance of Gravity due to Incline. |
|---|---|---|---|---|---|---|---|
| Degs. | Inches. | 1 in | Pounds per Ton. | Degs. | Inches. | 1 in | Pounds per Ton. |
| 1 | 0·63 | 57·29 | 39·08 | 19 | 12·39 | 2·90 | 729·27 |
| 2 | 1·26 | 28·63 | 78·18 | 20 | 13·10 | 2·74 | 766·12 |
| 3 | 1·88 | 19·09 | 117·24 | 21 | 13·82 | 2·60 | 802·74 |
| 4 | 2·51 | 14·29 | 156·26 | 22 | 14·54 | 2·47 | 839·12 |
| 5 | 3·15 | 11·42 | 195·24 | 23 | 15·27 | 2·35 | 875·23 |
| 6 | 3·78 | 9·51 | 234·14 | 24 | 16·02 | 2·24 | 911·09 |
| 7 | 4·42 | 8·14 | 272·98 | 25 | 16·78 | 2·14 | 946·66 |
| 8 | 5·06 | 7·11 | 311·74 | 26 | 17·56 | 2·05 | 981·94 |
| 9 | 5·70 | 6·31 | 350·40 | 27 | 18·34 | 1·96 | 1016·93 |
| 10 | 6·34 | 5·67 | 388·97 | 28 | 19·14 | 1·88 | 1051·61 |
| 11 | 6·99 | 5·14 | 427·41 | 29 | 19·95 | 1·80 | 1085·97 |
| 12 | 7·65 | 4·70 | 465·71 | 30 | 20·78 | 1·73 | 1120·0 |
| 13 | 8·31 | 4·33 | 503·88 | 31 | 21·62 | 1·66 | 1153·68 |
| 14 | 8·97 | 4·01 | 541·90 | 32 | 22·49 | 1·60 | 1187·02 |
| 15 | 9·64 | 3·73 | 579·75 | 33 | 23·37 | 1·54 | 1219·99 |
| 16 | 10·32 | 3·48 | 617·43 | 34 | 24·28 | 1·48 | 1252·58 |
| 17 | 11·0 | 3·27 | 654·90 | 35 | 25·20 | 1·42 | 1284·81 |
| 18 | 11·69 | 3·07 | 692·20 | | | | |

## Table 209.—Flat Wire Ropes: Strength and Weight.
(Dixon & Corbitt.)

| Sizes. | Weights per Fathom. | Charcoal Iron. | | Bessemer or Ingot Iron. | | Crucible Steel. | | Patent Steel. | | Plough Steel. | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Breaking Strain. | Working Load. | Breaking Strain. | Working Load. | Breaking Strain. | Working Load. | Breaking Strain. | Working Load. | Breaking Strain. | Working Load. |
| Ins. Ins. | Lbs. | Tons. | Cwts. | Tons. | Cwts. | Tons. | Cwts. | Tons. | Cwts. | Tons. | Cwts. |
| $2\frac{1}{8} \times \frac{7}{16}$ | 9 | 10 | 20 | 14 | 28 | 19 | 38 | 23 | 46 | 36 | 72 |
| $2\frac{3}{8} \times \frac{7}{16}$ | 10 | 12 | 24 | 16 | 32 | 22 | 44 | 27 | 54 | 42 | 84 |
| $2\frac{1}{2} \times \frac{1}{2}$ | 12 | 14 | 28 | 19 | 38 | 25 | 50 | 32 | 64 | 49 | 98 |
| $2\frac{3}{4} \times \frac{1}{2}$ | 14 | 16 | 32 | 22 | 44 | 29 | 58 | 36 | 72 | 56 | 112 |
| $3 \times \frac{9}{16}$ | 16 | 18 | 36 | 25 | 50 | 34 | 68 | 42 | 84 | 65 | 130 |
| $3\frac{1}{4} \times \frac{9}{16}$ | 18 | 21 | 42 | 29 | 58 | 38 | 76 | 48 | 96 | 74 | 148 |
| $3\frac{1}{2} \times \frac{5}{8}$ | 20 | 23 | 46 | 32 | 64 | 43 | 86 | 54 | 108 | 83 | 166 |
| $3\frac{3}{4} \times \frac{5}{8}$ | 22 | 26 | 52 | 36 | 72 | 49 | 98 | 61 | 122 | 93 | 186 |
| $4 \times \frac{11}{16}$ | 25 | 29 | 58 | 40 | 80 | 54 | 108 | 67 | 134 | 102 | 204 |
| $4\frac{1}{4} \times \frac{11}{16}$ | 28 | 32 | 64 | 44 | 88 | 58 | 116 | 73 | 146 | 115 | 230 |
| $4\frac{1}{2} \times \frac{3}{4}$ | 30 | 35 | 70 | 48 | 96 | 64 | 128 | 81 | 162 | 124 | 248 |
| $4\frac{5}{8} \times \frac{3}{4}$ | 32 | 37 | 74 | 52 | 104 | 70 | 140 | 88 | 176 | 135 | 270 |
| $4\frac{3}{4} \times \frac{13}{16}$ | 34 | 40 | 80 | 57 | 114 | 76 | 152 | 95 | 190 | 146 | 292 |
| $5 \times \frac{7}{8}$ | 36 | 44 | 88 | 62 | 124 | 83 | 166 | 104 | 208 | 160 | 320 |
| $5\frac{1}{8} \times \frac{7}{8}$ | 38 | 48 | 96 | 67 | 134 | 89 | 178 | 112 | 224 | 172 | 344 |
| $5\frac{1}{4} \times \frac{15}{16}$ | 40 | 52 | 104 | 72 | 144 | 96 | 192 | 120 | 240 | 184 | 368 |
| $5\frac{1}{2} \times 1$ | 42 | 56 | 112 | 78 | 156 | 104 | 208 | 130 | 260 | 200 | 400 |
| $5\frac{3}{4} \times 1\frac{1}{16}$ | 45 | 60 | 120 | 83 | 166 | 111 | 222 | 138 | 276 | 213 | 426 |
| $6 \times 1\frac{1}{8}$ | 48 | 64 | 128 | 90 | 180 | 120 | 240 | 150 | 300 | 228 | 456 |
| $3\frac{1}{4} \times \frac{7}{16}$ | 13 | 15 | 30 | 22 | 44 | 27 | 54 | 36 | 72 | 54 | 108 |
| $3\frac{1}{2} \times \frac{1}{2}$ | 16 | 18 | 36 | 26 | 52 | 32 | 64 | 43 | 86 | 64 | 128 |
| $3\frac{3}{4} \times \frac{1}{2}$ | 18 | 20 | 40 | 30 | 60 | 37 | 74 | 48 | 96 | 73 | 146 |
| $4 \times \frac{9}{16}$ | 21 | 24 | 48 | 34 | 64 | 43 | 86 | 56 | 112 | 85 | 170 |
| $4\frac{3}{8} \times \frac{9}{16}$ | 24 | 27 | 54 | 38 | 76 | 49 | 98 | 64 | 128 | 97 | 194 |
| $4\frac{5}{8} \times \frac{5}{8}$ | 27 | 30 | 60 | 43 | 86 | 55 | 110 | 72 | 144 | 108 | 216 |
| $5 \times \frac{5}{8}$ | 29 | 34 | 68 | 48 | 96 | 63 | 126 | 81 | 162 | 123 | 246 |
| $5\frac{1}{4} \times \frac{11}{16}$ | 32 | 38 | 76 | 53 | 106 | 70 | 140 | 89 | 178 | 135 | 270 |
| $5\frac{1}{2} \times \frac{11}{16}$ | 36 | 41 | 82 | 58 | 116 | 76 | 152 | 97 | 194 | 150 | 300 |
| $5\frac{3}{4} \times \frac{3}{4}$ | 39 | 46 | 92 | 65 | 130 | 84 | 168 | 108 | 216 | 162 | 324 |
| $6 \times \frac{3}{4}$ | 42 | 50 | 100 | 70 | 140 | 92 | 184 | 119 | 238 | 175 | 350 |
| $6\frac{1}{4} \times \frac{7}{8}$ | 44 | 54 | 108 | 76 | 162 | 99 | 199 | 126 | 252 | 187 | 374 |
| $6\frac{1}{2} \times \frac{7}{8}$ | 47 | 59 | 118 | 83 | 166 | 109 | 218 | 139 | 278 | 208 | 416 |
| $6\frac{3}{4} \times \frac{15}{16}$ | 50 | 63 | 126 | 89 | 178 | 117 | 234 | 149 | 298 | 224 | 448 |
| $7 \times 1$ | 54 | 68 | 136 | 96 | 192 | 126 | 232 | 160 | 320 | 240 | 480 |

## TABLE 210.—WIRE CORDS FOR CLOCKS, SASH-LINES, &c.: STRENGTH.
(Dixon & Corbitt.)

| No. | Diameter. | Copper. | | Phosphor Bronze. | | Iron. | | Steel. | | Patent Steel (Crucible or Open Hearth). | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Breaking Stress. | Working Load. | Breaking Stress. | Working Load. | Breaking Stress. | Working Load. | Breaking Stress. | Working Load. | Breaking Stress. | Working Load. |
| | Inch. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. |
| 4 | ·108 | 181 | 45 | 363 | 90 | 318 | 79 | 493 | 123 | 697 | 174 |
| $3\frac{1}{2}$ | ·117 | 213 | 53 | 428 | 107 | 374 | 93 | 576 | 144 | 817 | 204 |
| 3 | ·126 | 248 | 62 | 496 | 124 | 435 | 108 | 671 | 167 | 949 | 237 |
| $2\frac{3}{4}$ | ·135 | 286 | 71 | 572 | 143 | 500 | 125 | 778 | 194 | 1127 | 281 |
| $2\frac{1}{2}$ | ·144 | 324 | 81 | 648 | 162 | 565 | 141 | 875 | 219 | 1240 | 310 |
| 2 | ·153 | 367 | 91 | 734 | 183 | 640 | 160 | 1005 | 251 | 1410 | 352 |
| $1\frac{7}{8}$ | ·171 | 459 | 114 | 918 | 229 | 802 | 200 | 1248 | 312 | 1750 | 437 |
| $1\frac{3}{4}$ | ·189 | 560 | 140 | 1121 | 280 | 981 | 245 | 1539 | 384 | 2123 | 530 |
| $1\frac{1}{2}$ | ·207 | 671 | 167 | 1342 | 335 | 1173 | 293 | 1815 | 454 | 2560 | 640 |
| $1\frac{3}{8}$ | ·225 | 790 | 197 | 1580 | 395 | 1382 | 345 | 2129 | 532 | 2974 | 743 |
| $1\frac{1}{4}$ | ·252 | 992 | 248 | 1984 | 496 | 1735 | 434 | 2673 | 668 | 3790 | 947 |
| $1\frac{1}{8}$ | ·288 | 1294 | 323 | 2588 | 647 | 2264 | 566 | 3500 | 875 | 5606 | 1400 |
| 1 | ·324 | 1651 | 410 | 3283 | 820 | 2865 | 716 | 4439 | 1109 | 6286 | 1500 |

*Note.*—Cords made of six strands of six wires each.

## TABLE 211.—SUNDRY WIRE CORDS AND ROPES.
(Dixon & Corbitt.)

### GALVANIZED SIGNAL AND FENCING STRAND.

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7 Wires. No. | 00 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Diameter. Inch | ·345 | ·318 | ·294 | ·267 | ·255 | ·240 | ·213 | ·198 | ·186 | ·171 | ·147 | ·120 |
| Weight per 100 yards. Lbs. | 73 | $62\frac{1}{2}$ | 53 | 44 | 40 | $35\frac{1}{2}$ | $27\frac{3}{4}$ | $24\frac{1}{4}$ | $21\frac{1}{2}$ | 18 | $13\frac{1}{4}$ | 9 |

### CAGE GUIDE ROPES.

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Inches circumference | $2\frac{1}{4}$ | $2\frac{1}{2}$ | $2\frac{3}{4}$ | 3 | $3\frac{1}{4}$ | $3\frac{1}{2}$ | $3\frac{3}{4}$ | 4 | $4\frac{1}{4}$ | $4\frac{1}{2}$ | $4\frac{3}{4}$ | 5 |
| Weight per fathom. Lbs. | $6\frac{3}{4}$ | $8\frac{1}{4}$ | 10 | $11\frac{3}{4}$ | $13\frac{3}{4}$ | 16 | $18\frac{1}{4}$ | 21 | $23\frac{1}{2}$ | $26\frac{1}{2}$ | $29\frac{1}{2}$ | $32\frac{1}{2}$ |

### ELECTRO-GILT AND SILVER PICTURE CORDS.

| | | | | | | |
|---|---|---|---|---|---|---|
| Reference No. | 1 | 2 | 3 | 4 | 5 | 6 |
| Breaking strain in lbs. | 48 | 90 | 120 | 200 | 400 | 600 |
| Working load | 12 | 22 | 30 | 50 | 100 | 150 |

## TABLE 212.—ROUND HEMP ROPES: WEIGHT AND STRENGTH.

(Dixon & Corbitt.)

| Sizes. | | Tarred Russian. | | | White Manilla. | | |
|---|---|---|---|---|---|---|---|
| Diameter. | Circumference. | Weight per Fathom. | Breaking Strain. | Working Load. | Weight per Fathom. | Breaking Strain. | Working Load. |
| Inches. | Inches. | Lbs. | Tons. | Cwts. | Lbs. | Tons. | Cwts. |
| $\frac{5}{8}$ | 2 | 1·0 | 1·0 | 4 | ·7 | 1·2 | 5 |
| $\frac{23}{32}$ | $2\frac{1}{4}$ | 1·2 | 1·2 | 5 | ·9 | 1·5 | 6 |
| $\frac{25}{32}$ | $2\frac{1}{2}$ | 1·5 | 1·5 | 6 | 1·2 | 2·1 | 8 |
| $\frac{7}{8}$ | $2\frac{3}{4}$ | 1·8 | 1·8 | 8 | 1·3 | 2·3 | 9 |
| $\frac{15}{16}$ | 3 | 2·2 | 2·2 | 9 | 1·6 | 2·8 | 11 |
| $1\frac{1}{32}$ | $3\frac{1}{4}$ | 2·5 | 2·5 | 10 | 1·9 | 3·3 | 13 |
| $1\frac{1}{8}$ | $3\frac{1}{2}$ | 3·0 | 3·0 | 12 | 2·2 | 3·8 | 15 |
| $1\frac{3}{16}$ | $3\frac{3}{4}$ | 3·5 | 3·5 | 14 | 2·6 | 4·5 | 18 |
| $1\frac{1}{4}$ | 4 | 4·0 | 4·0 | 16 | 2·9 | 5·0 | 20 |
| $1\frac{11}{32}$ | $4\frac{1}{4}$ | 4·5 | 4·5 | 18 | 3·3 | 5·7 | 23 |
| $1\frac{7}{16}$ | $4\frac{1}{2}$ | 5·0 | 5·0 | 20 | 3·7 | 6·4 | 25 |
| $1\frac{19}{32}$ | 5 | 6·2 | 6·2 | 25 | 4·5 | 7·8 | 31 |
| $1\frac{3}{4}$ | $5\frac{1}{2}$ | 7·4 | 7·4 | 29 | 5·5 | 9·6 | 38 |
| $1\frac{29}{32}$ | 6 | 8·8 | 8·8 | 35 | 6·5 | 11·3 | 45 |
| $2\frac{1}{16}$ | $6\frac{1}{2}$ | 10·4 | 10·4 | 41 | 7·6 | 13·3 | 53 |
| $2\frac{1}{4}$ | 7 | 12·0 | 12·0 | 48 | 8·9 | 15·5 | 62 |
| $2\frac{3}{8}$ | $7\frac{1}{2}$ | 13·8 | 13·8 | 55 | 10·2 | 17·8 | 71 |
| $2\frac{17}{32}$ | 8 | 15·7 | 15·7 | 60 | 11·6 | 20·3 | 81 |
| $2\frac{3}{4}$ | $8\frac{1}{2}$ | 17·7 | 17·7 | 68 | 13·0 | 22·7 | 91 |
| $2\frac{27}{32}$ | 9 | 19·8 | 19·8 | 76 | 14·6 | 25·5 | 102 |
| 3 | $9\frac{1}{2}$ | 22·1 | 22·1 | 88 | 16·3 | 28·5 | 114 |
| $3\frac{3}{16}$ | 10 | 24·4 | 24·4 | 99 | 18·0 | 31·5 | 126 |
| $3\frac{3}{8}$ | $10\frac{1}{2}$ | 27·0 | 27·0 | 108 | 19·9 | 34·8 | 139 |
| $3\frac{1}{2}$ | 11 | 29·6 | 29·6 | 116 | 21·8 | 38·1 | 152 |
| $3\frac{5}{8}$ | $11\frac{1}{2}$ | 32·4 | 32·4 | 131 | 23·8 | 41·6 | 166 |
| $3\frac{13}{16}$ | 12 | 35·2 | 35·2 | 141 | 26·0 | 45·5 | 182 |
| 4 | $12\frac{1}{2}$ | 38·2 | 38·2 | 153 | 28·2 | 49·3 | 197 |
| $4\frac{5}{32}$ | 13 | 41·4 | 41·4 | 167 | 30·5 | 53·9 | 215 |
| $4\frac{3}{16}$ | $13\frac{1}{2}$ | 44·6 | 44·6 | 176 | 32·8 | 57·4 | 229 |
| $4\frac{7}{16}$ | 14 | 48·0 | 48·0 | 192 | 35·3 | 61·7 | 247 |
| $4\frac{5}{8}$ | $14\frac{1}{2}$ | 51·5 | 51·5 | 204 | 37·8 | 66·1 | 264 |
| $4\frac{3}{4}$ | 15 | 55·0 | 55·0 | 220 | 40·5 | 70·0 | 280 |
| 5 | 16 | 62·6 | 62·6 | 248 | 46·1 | 80·6 | 322 |
| $5\frac{13}{32}$ | 17 | 70·7 | 70·7 | 280 | 52·0 | 91·0 | 364 |
| $5\frac{3}{4}$ | 18 | 79·2 | 79·2 | 317 | 58·3 | 102 | 408 |

## Table 213.—Flat Hemp Ropes: Weight and Strength.

(Dixon & Corbitt.)

| Sizes. | Tarred Russian. | | | Combined Russian and Manilla. | | |
|---|---|---|---|---|---|---|
| | Weight per Fathom. | Breaking Stress. | Working Load. | Weight per Fathom. | Breaking Stress. | Working Load. |
| Inches. | Pounds. | Tons. | Cwts. | Pounds. | Tons. | Cwts. |
| Four Ropes. | | | | | | |
| $3\frac{1}{2} \times 1$ | 10 | 10 | 20 | $9\frac{1}{2}$ | 11 | 22 |
| $4 \times 1\frac{1}{16}$ | $13\frac{1}{2}$ | $13\frac{1}{2}$ | 27 | $12\frac{1}{2}$ | 15 | 30 |
| $4\frac{1}{2} \times 1\frac{3}{16}$ | 17 | 17 | 34 | 16 | 19 | 38 |
| $5 \times 1\frac{3}{8}$ | 21 | 21 | 42 | $19\frac{1}{2}$ | 23 | 46 |
| $5\frac{1}{2} \times 1\frac{1}{2}$ | 25 | 25 | 50 | $23\frac{1}{2}$ | 28 | 56 |
| $6 \times 1\frac{5}{8}$ | 30 | 30 | 60 | 28 | 33 | 66 |
| $6\frac{1}{2} \times 1\frac{3}{4}$ | 34 | 34 | 68 | 32 | 38 | 76 |
| $7 \times 1\frac{7}{8}$ | 38 | 38 | 76 | 36 | 43 | 86 |
| $7\frac{1}{2} \times 2$ | 43 | 43 | 86 | 40 | 48 | 96 |
| Six Ropes. | | | | | | |
| $4 \times \frac{13}{16}$ | 10 | 10 | 20 | $9\frac{1}{2}$ | 11 | 22 |
| $4\frac{1}{2} \times \frac{15}{16}$ | 13 | 13 | 26 | 12 | 14 | 28 |
| $5 \times 1$ | 16 | 16 | 32 | $14\frac{1}{2}$ | 17 | 34 |
| $5\frac{1}{8} \times 1\frac{1}{8}$ | 19 | 19 | 38 | 16 | 20 | 40 |
| $6 \times 1\frac{1}{4}$ | 22 | 22 | 24 | 20 | 24 | 28 |
| $6\frac{1}{2} \times 1\frac{3}{8}$ | 25 | 25 | 50 | $22\frac{1}{2}$ | 27 | 54 |
| $7 \times 1\frac{1}{2}$ | 28 | 28 | 56 | 25 | 30 | 60 |
| $7\frac{1}{2} \times 1\frac{1}{2}$ | 32 | 32 | 64 | 29 | 34 | 68 |
| $8 \times 1\frac{5}{8}$ | 36 | 36 | 72 | 33 | 39 | 78 |

## TABLE 214.—HEMP ROPES AND WIRE ROPES: SIZE AND WEIGHT FOR EQUAL STRENGTHS.

(J. Shaw.)

### I. ROUND ROPES.

| Hemp. | | Crucible Cast Steel. | | Charcoal Wire. | | Strength. | |
|---|---|---|---|---|---|---|---|
| Circumference. | Weight per Fathom (approximate). | Circumference. | Weight per Fathom (approximate). | Circumference. | Weight per Fathom (approximate). | Breaking Stress. | Working Load (approximate). |
| Inches. | Pounds. | Inches. | Pounds. | Inches. | Pounds. | Tons. | Cwts. |
| $3\frac{1}{2}$ | 3 | $1\frac{1}{4}$ | $1\frac{1}{2}$ | $1\frac{1}{2}$ | 2 | $2\frac{3}{4}$ | 9 |
| 4 | 4 | $1\frac{3}{8}$ | $1\frac{3}{4}$ | $1\frac{3}{4}$ | $2\frac{3}{4}$ | 4 | 15 |
| $4\frac{1}{2}$ | 5 | $1\frac{1}{2}$ | 2 | 2 | $3\frac{1}{4}$ | 6 | 20 |
| 5 | $6\frac{1}{2}$ | $1\frac{3}{4}$ | $2\frac{3}{4}$ | $2\frac{1}{4}$ | $4\frac{1}{2}$ | $7\frac{1}{2}$ | 24 |
| $5\frac{1}{2}$ | $7\frac{1}{2}$ | $1\frac{7}{8}$ | 3 | $2\frac{1}{2}$ | $5\frac{1}{2}$ | $9\frac{1}{2}$ | 30 |
| 6 | $8\frac{1}{2}$ | 2 | $3\frac{1}{4}$ | $2\frac{3}{4}$ | $6\frac{1}{2}$ | $11\frac{1}{2}$ | 36 |
| $6\frac{1}{2}$ | 10 | $2\frac{1}{4}$ | $4\frac{1}{2}$ | 3 | $7\frac{3}{4}$ | 14 | 45 |
| 7 | 12 | $2\frac{1}{2}$ | $5\frac{1}{2}$ | $3\frac{1}{4}$ | $8\frac{1}{2}$ | 16 | 52 |
| $7\frac{1}{2}$ | 14 | $2\frac{5}{8}$ | 6 | $3\frac{1}{2}$ | $10\frac{1}{2}$ | 19 | 62 |
| 8 | 16 | $2\frac{3}{4}$ | $6\frac{1}{2}$ | $3\frac{3}{4}$ | $12\frac{1}{2}$ | 22 | 74 |
| $8\frac{1}{2}$ | 18 | 3 | $7\frac{3}{4}$ | 4 | 14 | 25 | 80 |
| 9 | 20 | $3\frac{1}{4}$ | $9\frac{1}{4}$ | $4\frac{1}{4}$ | 16 | 28 | 95 |
| $9\frac{1}{2}$ | 23 | $3\frac{1}{2}$ | $10\frac{3}{4}$ | $4\frac{1}{2}$ | 18 | 32 | 105 |
| 10 | 26 | $3\frac{3}{4}$ | $12\frac{1}{2}$ | $4\frac{3}{4}$ | 20 | 36 | 120 |
| $10\frac{1}{2}$ | 29 | 4 | $14\frac{1}{4}$ | 5 | 22 | 40 | 135 |
| 11 | 31 | $4\frac{1}{8}$ | 15 | $5\frac{1}{4}$ | 25 | 45 | 150 |
| $11\frac{1}{2}$ | 34 | $4\frac{1}{4}$ | 16 | $5\frac{1}{2}$ | 28 | 50 | 160 |
| 12 | 37 | $4\frac{1}{2}$ | 18 | $5\frac{3}{4}$ | 31 | 55 | 170 |
| 13 | 41 | $4\frac{3}{4}$ | 20 | 6 | 35 | 60 | 180 |

### II. FLAT ROPES.

| Sizes. Inches. | | Sizes. Inches. | | Sizes. Inches. | | | |
|---|---|---|---|---|---|---|---|
| $3\frac{1}{2}\times 1$ | 12 | ... | ... | $2\frac{1}{4}\times\frac{1}{2}$ | 10 | 18 | 40 |
| $4\times 1\frac{1}{4}$ | 15 | ... | ... | $2\frac{1}{2}\times\frac{1}{2}$ | 12 | 20 | 45 |
| $4\frac{1}{2}\times 1\frac{1}{2}$ | 20 | ... | ... | $2\frac{3}{4}\times\frac{5}{8}$ | 14 | 23 | 51 |
| $5\times 1\frac{3}{4}$ | 24 | $2\frac{1}{4}\times\frac{1}{2}$ | 10 | $3\times\frac{5}{8}$ | 16 | 27 | 56 |
| $5\frac{1}{2}\times 1\frac{3}{4}$ | 27 | $2\frac{1}{2}\times\frac{1}{2}$ | 12 | $3\frac{1}{4}\times\frac{5}{8}$ | 18 | 30 | 60 |
| $6\frac{1}{4}\times 1\frac{7}{8}$ | 30 | $2\frac{3}{4}\times\frac{5}{8}$ | 14 | $3\frac{1}{2}\times\frac{5}{8}$ | $20\frac{1}{2}$ | 33 | 68 |
| $6\frac{1}{2}\times 2$ | 33 | $3\times\frac{5}{8}$ | 16 | $3\frac{3}{4}\times\frac{3}{4}$ | $22\frac{1}{2}$ | 36 | 78 |
| $7\times 2$ | 36 | $3\frac{1}{4}\times\frac{5}{8}$ | $18\frac{1}{2}$ | $4\times\frac{3}{4}$ | 25 | 39 | 90 |
| $7\frac{1}{4}\times 2\frac{1}{8}$ | 39 | $3\frac{1}{2}\times\frac{5}{8}$ | 21 | $4\frac{1}{4}\times\frac{7}{8}$ | 28 | 42 | 106 |
| $8\times 2\frac{1}{4}$ | 42 | $3\frac{3}{4}\times\frac{3}{4}$ | $22\frac{1}{2}$ | $4\frac{1}{2}\times\frac{7}{8}$ | 32 | 45 | 118 |

TABLE 215.—STEEL WIRE ROPES: BREAKING STRESS. (J. Shaw.)

| Plough Steel Wire Rope. | | Hard Steel Ropes. | | Iron Wire Guides, or Conducting Rods. | |
|---|---|---|---|---|---|
| Circumference. | Breaking Stress. | Circumference. | Breaking Stress. | Circumference. | Weight per Fathom. |
| Inches. | Tons. | Inches. | Tons. | Inches. | Pounds. |
| $1\frac{1}{2}$ | 12 | $1\frac{1}{2}$ | $9\frac{1}{2}$ | $2\frac{3}{4}$ | 13 |
| $1\frac{3}{4}$ | $15\frac{1}{2}$ | $1\frac{3}{4}$ | $11\frac{1}{2}$ | 3 | 15 |
| 2 | 18 | 2 | 14 | $3\frac{1}{4}$ | 18 |
| $2\frac{1}{4}$ | 24 | $2\frac{1}{4}$ | 17 | $3\frac{1}{2}$ | 21 |
| $2\frac{1}{2}$ | 27 | $2\frac{1}{2}$ | 21 | $3\frac{3}{4}$ | 24 |
| $2\frac{3}{4}$ | $31\frac{1}{2}$ | $2\frac{3}{4}$ | 26 | 4 | 28 |
| 3 | 38 | 3 | 31 | | |
| $3\frac{1}{4}$ | 46 | $3\frac{1}{4}$ | 37 | | |
| $3\frac{1}{2}$ | 53 | $3\frac{1}{2}$ | 42 | | |
| $3\frac{3}{4}$ | 59 | $3\frac{3}{4}$ | 50 | | |
| 4 | 68 | 4 | 55 | | |
| $4\frac{1}{4}$ | 76 | $4\frac{1}{4}$ | 63 | | |
| $4\frac{1}{2}$ | 88 | $4\frac{1}{2}$ | 71 | | |
| 5 | 100 | 5 | 90 | | |

**Duboul's Experiments on the Strength of Ropes.**

M. Duboul tested ropes and cables of white hemp and tarred hemp, Italian, Russian, and French; of long fibre, hand spun, with from fifty to fifty-five twists to the yard; $1\frac{1}{2}$ yards of rope yarn sufficing to make one yard of cable. A selection of results is given in Table 216.

Flat tarred ropes were proved to a mean strength of from 3·43 tons to 3·75 tons per square inch, rupture taking place at the points of attachment. The extension rarely exceeded from 5 to 6 per cent.

The average ultimate tensile strength of rope was as follows:—

| | Tons. | | Tons. | |
|---|---|---|---|---|
| White hemp | 4·76 | to | 5·08 | per square inch. |
| Tarred hemp | 3·54 | „ | 3·81 | „ „ „ |
| White Manilla | 4·44 | „ | 4·76 | „ „ „ |
| White aloes | 2·54 | „ | 3·17 | „ „ „ |
| Flat ropes of tarred hemp, or Tarred Manilla | 3·54 | „ | 3·81 | „ „ „ |
| Esparto and cocoa fibres | 1·00 | „ | 1·25 | „ „ „ |

M. Duboul deduced from results of practice that round ropes and cables may be worked at a stress equal to one-third of the ultimate strength; and flat ropes at one-fourth. In ordinary practice, the proportion is often not more than from one-sixth to one-eighth.

TABLE 216.—RESULTS OF TESTS OF ROUND ROPES.

(M. Duboul.)

| | | White Hemp. | | Tarred Hemp. | | White Manilla. | | White Aloes. | |
|---|---|---|---|---|---|---|---|---|---|
| Circumference before rupture . . | Inches | 4·33 | 4·33 | 4·25 | 4·25 | 3·94 | 3·94 | 4·33 | 4·33 |
| " after " . . | " | 3·86 | 3·74 | 3·70 | 3·74 | 3·27 | 3·39 | 3·54 | 3·66 |
| Length tested . . . . . . | Feet | 32·8 | 32·8 | 32·8 | 32·8 | 32·8 | 32·8 | 32·8 | 32·8 |
| " measured for testing extension . . . . . . | " | 13·1 | 13·1 | 13·1 | 13·1 | 13·1 | 13·1 | 13·1 | 13·1 |
| Extension . . . . . . | Inches | 27·2 | 28·3 | 25·6 | 26·4 | 23·2 | 22·8 | 26·0 | 26·8 |
| Section of the four strands . | Square Inch | ·819 | ·819 | ·819 | ·819 | ·819 | ·819 | ·819 | ·819 |
| Section of the piece . . . . | " | 1·490 | 1·490 | 1·481 | 1·481 | 1·246 | 1·246 | 1·491 | 1·491 |
| Resistance . . . . . . . | Tons | 7·94 | 7·43 | 5·22 | 5·64 | 5·44 | 5·96 | 3·99 | 4·45 |
| " of the four strands per square inch . . . | " | 9·78 | 9·02 | 6·35 | 6·86 | 6·60 | 7·24 | 4·83 | 5·40 |
| " of the piece per square inch . . . . . | " | 5·27 | 4·95 | 3·49 | 3·87 | 4·32 | 4·76 | 2·67 | 2·98 |
| Weight of the whole piece tested . | Pounds | 17·4 | 17·6 | 18·7 | 19·6 | 15·0 | 15·2 | 15·0 | 15·4 |

M. Duboul estimates that ropes and cables of galvanized charcoal-iron wire unannealed, have two-tenths of the diameter of hemp cables of equal strength; or three-tenths for annealed wire.

| | Ultimate Strength per Square Inch, Section of Metal. | Extension. | Elasticity. |
|---|---|---|---|
| Rope of unannealed wire | 25·4 to 31·7 tons | 7 to 9 % | 1 to 2 % |
| „ annealed „ | 22·2 to 25·4 „ | 12 to 15 „ | 3 to 4 „ |

The galvanized wire tested by itself, yields 10 per cent. more resistance to rupture than in the form of rope.

Wire-ropes for mining service, of the first quality, have an ultimate strength of from 40 to 45 tons per square inch of metal section.

Cast-steel wire ropes stretch from 4 to 6 per cent. before rupture, with an elastic limit of from 2 to 3½ per cent. They bear three-fourths of the breaking stress before exhibiting any sign of failure.

TABLE 217.—STEEL WIRE ROPE, FOR STANDING RIGGING. (Admiralty.)

| Size of Rope (Girth). | Number of Strands. | Wires in one Strand. | Thickness of Wires. | Weight per Fathom. | Length of one Coil. | Breaking Stress (Minimum). |
|---|---|---|---|---|---|---|
| Inches. | Strands. | Wires. | I. W. G. | Pounds. | Fathoms. | Tons. |
| 8 | 6 | 19 | 6 | 62 | 100 | 160 |
| 7½ | 6 | 19 | 7 | 53 | 100 | 141 |
| 7 | 6 | 19 | 8 | 46 | 100 | 123 |
| 6½ | 6 | 19 | 6 | 40 | 100 | 106 |
| 6 | 6 | 19 | 10 | 34 | 100 | 90 |
| 5½ | 6 | 19 | 10 | 28 | 100 | 76 |
| 5 | 6 | 19 | 12 | 23 | 100 | 63 |
| 4½ | 6 | 19 | 12 | 19 | 150 | 51 |
| 4 | 6 | 19 | 14 | 15½ | 150 | 40 |
| 3½ | 6 | 7 | 10 | 11½ | 150 | 32 |
| 3¼ | 6 | 7 | 11 | 10 | 150 | 27 |
| 3 | 6 | 7 | 12 | 8 | 200 | 24 |
| 2¾ | 6 | 7 | 13 | 7 | 200 | 19 |
| 2½ | 6 | 7 | 13 | 6 | 200 | 16 |
| 2¼ | 6 | 7 | 14 | 5 | 200 | 13 |
| 2 | 6 | 7 | 15 | 4 | 200 | 10 |
| 1¾ | 6 | 7 | 16 | 3 | 200 | 8 |
| 1½ | 6 | 7 | 18 | 2 | 200 | 6 |
| 1¼ | 6 | 7 | 18 | 1½ | 200 | 3¾ |
| 1 | 6 | 7 | 20 | 1 | 200 | 2½ |

TABLE 218.—STEEL WIRE ROPES, FOR HAWSERS AND RUNNING RIGGING.

(Admiralty.)

| Size of Rope (Girth). | Number of Strands. | Wires in one Strand. | Thickness of Wires. | Weight per Fathom. | Length of one Coil. | Breaking Stress (Minimum). |
|---|---|---|---|---|---|---|
| Inches. | Strands. | Wires. | I. W. G. | Pounds. | Fathoms. | Tons. |
| 8 | 6 | 30 | 9 | ... | 150 | ... |
| 7 | 6 | 30 | 11 | ... | 150 | ... |
| $6\frac{1}{2}$ | 6 | 30 | 12 | 35 | 150 | 98 |
| 6 | 6 | 30 | 12 | 31 | 150 | 84 |
| $5\frac{1}{2}$ | 6 | 25 | 12 | 28 | 150 | 71 |
| 5 | 6 | 25 | 13 | 23 | 150 | 59 |
| $4\frac{1}{2}$ | 6 | 12 | 12 | 15 | 150 | 39 |
| 4 | 6 | 12 | 13 | 12 | 240 | 31 |
| $3\frac{1}{2}$ | 6 | 12 | 14 | 9 | 360 | 24 |
| $3\frac{1}{4}$ | 6 | 12 | 15 | 8 | 360 | 20 |
| 3 | 6 | 12 | 16 | 7 | 360 | 17 |
| $2\frac{3}{4}$ | 6 | 12 | 17 | $5\frac{1}{2}$ | 360 | $14\frac{1}{2}$ |
| $2\frac{1}{2}$ | 6 | 12 | 17 | $4\frac{1}{2}$ | 360 | $11\frac{3}{4}$ |
| $2\frac{1}{4}$ | 6 | 12 | 18 | $3\frac{3}{4}$ | 300 | 9 |
| 2 | 6 | 12 | 19 | $2\frac{3}{4}$ | 300 | 7 |
| $1\frac{3}{4}$ | 6 | 12 | 20 | 2 | 300 | $5\frac{1}{2}$ |
| $1\frac{1}{2}$ | 6 | 12 | 21 | $1\frac{3}{4}$ | 300 | 4 |
| $1\frac{1}{4}$ | 6 | 12 | 22 | $1\frac{1}{4}$ | 300 | $2\frac{7}{8}$ |
| 1 | 6 | 12 | 24 | $\frac{3}{4}$ | 300 | $1\frac{3}{4}$ |

**Resistance of Ropes to Bending Stress.**

The resistance of ropes to bending stress in passing over a pulley or a barrel is expressed by the following formulas, the equivalents in English measures of Longraire's formulas:—

*Hemp Ropes, either White or Tarred.*

$$S = \cdot 0328\ T\ \frac{w}{D} \qquad (125)$$

*Iron Wire Ropes (Hemp Core).*

$$S = (3\cdot 61 + \cdot 00262\ T)\ \frac{w}{D} \qquad (126)$$

*Steel Wire Ropes (Hemp Core).*

$$S = (6{\cdot}314 + {\cdot}00262\ T)\ \frac{w}{D} \qquad . \quad . \ (127)$$

*Steel Wire Ropes, rusted.*

$$S = (5{\cdot}412 + {\cdot}00262\ T)\ \frac{w}{D} \qquad . \quad . \quad . \ (128)$$

*Steel Wire Ropes, Lubricated in Oil Bath.*

$$S = (3{\cdot}428 + {\cdot}00172\ T)\ \frac{w}{D} \qquad . \quad . \ (129)$$

$S$ = resistance to bending stress; or the total tensile stress or pull minus the resisting stress in the rope, in the advancing limb of the rope.

$T$ = resisting stress on the rope, in the advancing limb of the rope.

$w$ = weight of rope per fathom, in pounds.

$D$ = diameter of pulley or barrel, in feet.

The foregoing formulas apply to ropes which are new or nearly new; and for wire ropes of wire 3 millimetres, or about ⅛ inch thick. The resistance may be reduced ultimately by wear by 20 per cent. for iron ropes, and 33 per cent. for steel ropes. The experiments were made with wire ropes of from 6 lbs. to 13 lbs. per fathom, or from ·83 inch to 1·30 inch in diameter.

## CHAINS AND CHAIN-CABLES.

Cables for use in the naval and merchant service are made of round iron, in lengths of 15 fathoms, with stud-links. For standing rigging and crane chain, short or unstudded links are employed.

Chains are made of puddled iron, bars of which have, or ought to have, an ultimate tensile strength of 23 tons per square inch, stretching from 20 to 25 per cent. in a length of 10 inches; with a contraction of sectional area of from 45 to 50 per cent.

The links of chain-cables and short links generally are geometrically similar for all sizes, according to the following proportions, which are those of the links after having been submitted to the proof stress: the length of the common stud-link being 6 diameters, and the width about 3½ diameters, whilst the length and width of the short-link are respectively about 5 diameters and 3½ diameters.

| | | Stud-Link. | Short-Link. |
|---|---|---|---|
| | Diameter of iron . . | 1 | 1 |
| Common Links | Length of link outside . | 6 | 4·9 |
| | Width of link outside . | 3·6 | 3·5 |
| | Radius of each end inside | ·58 | ·60 |
| | Length of stud at crown. | 1·6 | — |
| | Width in parts of length | 60 per cent. | 71 per cent. |
| Enlarged Links | Diameter of iron . . | 1·1 | 1·1 |
| | Length of link outside . | 6·5 | 5·7 |
| | Width of link outside . | 4·0 | 3·8 |
| | Radius of each end inside | ·64 | ·63 |
| End Links | Diameter of iron . . | 1·2 | 1·2 |
| | Length of link outside . | 6·5 | 6·6 |
| | Width of link outside . | 4·0 | 4·1 |

The length of one link varies as the size or diameter, whilst the weight is as the cube of the diameter. The weight per unit of length,—say, one fathom,—varies, therefore, as the square of the diameter, and is expressed by the following formulæ, in which $d$ is the size or diameter in inches, and W is the weight per fathom in pounds :—

(Stud-link chains) . . . $W = 53{\cdot}76\, d^2$ . . . (130)

(Short-link or crane chain) . $W = 55\, d^2$ . . . . (131)

The proof tensile strength also varies as the square of the diameter, and therefore it varies as the weight.

| | Stud-Link. | Short-Link. | |
|---|---|---|---|
| The actual ultimate strength of good ordinary cable, in tons . . . | $=29d^2$ to $26{\cdot}7d^2$ | $27{\cdot}3d^2$ to $25{\cdot}1d^2$ | (132) |
| The statutory ultimate strength in tons . . . | $=27d^2$ to $25{\cdot}2d^2$ | $24d^2$ . . | (133) |
| The statutory proof strength in tons . | $=18d^2$ | $12d^2$ . . . . | (134) |
| The safe-working stress (half the proof strength) . | $= 9d^2$ | $6d^2$ . . . | (135) |

It is here shown that whilst the actual ultimate strength (132) of short-links is little less than that of stud-links, the

proof stress and the safe-working stress, (134) and (135), for the short-links, are only two-thirds of those for the stud-links, by reason of the lower elastic limit of the short links.

The Tables 219 and 220, from which the foregoing formulæ have been deduced, give the dimensions, weight, and strength of stud-link and short-link chain-cables. In Table 220, for short-links, there are no statutory tests for cables above $1\frac{5}{8}$ inches in diameter; but the appropriate stresses, with actual strengths for the larger sizes, calculated and supplied by Mr. T. Traill (in "*Chain-Cables and Chains*") are added in the table. In the second last column are given the safe-working strengths of cables, the factor of strength averaging for stud-links a little over 3; and for short-links about $4\frac{1}{4}$.

The safe-working load in tons is approximately expressed by the following formulæ:—

$$\text{Short-link chain} \quad . \quad . \quad \frac{D^2}{10} \quad . \quad . \quad (136)$$

$$\text{Stud-link chain} . \quad . \quad . \quad \frac{D^2}{7} \quad . \quad . \quad (137)$$

in which D is the diameter of the iron in eighths of an inch. The values thus obtained are about 7 per cent. too high for the short-link chain, and about 1 per cent. too high for the stud-link chain.

The Admiralty have special proportions for iron chain rigging and crane work, for which the sizes and weights are given in Table 222. The Admiralty chain moorings are noted in Table 221, in which the sizes, weights, and proof stresses are given. They are of unstudded or open links, and these are shaped differently from the ordinary short-link, being made thicker at the ends, the wearing parts. Mooring chains are in consequence heavier than short-link chains of the same sizes.

The India Office prescribe for all services, except Marine, short-link chains, of which the common links are not to exceed $4\frac{1}{2}$ diameters in length, and $3\frac{1}{4}$ diameters in width. The weight and conditions of test are given in Table 223.

In the Trinity House contracts, it is specified that mooring chains, chain cables, crane and rigging chains, and appurtenances, except the stay-pins and steel pins, are to be of fibrous iron, to have a tensile stress of not less than 23 tons per square inch, with a contraction of sectional area at the fracture of not less than 40 per cent. of the original area. The cast iron of which the stay-pins are made is to have a compressive stress of not less than 52 tons per square inch of

TABLE 219.—STUD-LINK CHAIN-CABLES: DIMENSIONS, WEIGHT, AND STRENGTH.

| Diameter of Iron. | Length of One Link, Outside. | Width of One Link, Outside. | Radius of End of Link, Inside. | Length of Stud at Crown. | Weight of | | Statutory Proof Tensile Stress, for each 15 Fathoms separately. | Statutory Ultimate Strength or Breaking Stress, on Three Links in each 15 Fathoms. | Actual Breaking Stress. | | Safe-Working Stress (Half the Proof Stress). | Ultimate or Breaking Stress per Square Inch of Good Ordinary Cable. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 100 Fathoms. | One Fathom (Six Feet). | | | Good Ordinary Cable. | High Breaking Stress. | | |
| Inches. | Inches. | Inches. | Inches. | Inches. | Cwts. | Pounds. | Tons. | Tons. | Tons. | Tons. | Tons. | Tons. |
| 7/16 | 2 5/8 | 1 19/32 | 1/4 | 23/32 | 9·2 | 11·3 | 3·4 | 5·1 | 5·4 | 5 3/4 | 1·7 | 18·0 |
| 1/2 | 3 | 1 13/16 | 9/32 | 13/16 | 12 | 13·4 | 4·5 | 6 3/4 | 7 1/8 | 7·6 | 2 1/4 | 18·1 |
| 9/16 | 3 3/8 | 2 1/32 | 11/32 | 29/32 | 15·2 | 17·2 | 5 5/8 | 8·4 | 9 | 9 5/8 | 2·81 | 18·1 |
| 5/8 | 3 3/4 | 2 1/4 | 3/8 | 1 | 18·75 | 21 | 7 | 10·5 | 11·2 | 11·9 | 3 1/2 | 18·2 |
| 11/16 | 4 1/8 | 2 15/32 | 13/32 | 1 3/32 | 22·7 | 25·4 | 8·5 | 12 3/4 | 13·6 | 14·5 | 4 1/4 | 18·3 |
| 3/4 | 4 1/2 | 2 11/32 | 7/16 | 1 3/16 | 27 | 30·2 | 10 1/8 | 15 1/8 | 16·2 | 17·3 | 5 1/16 | 18·3 |
| 13/16 | 4 7/8 | 2 15/16 | 15/32 | 1 5/16 | 31·7 | 35·5 | 11 7/8 | 17·8 | 19 | 20 3/8 | 5·94 | 18·3 |
| 7/8 | 5 1/4 | 3 5/32 | 17/32 | 1 13/32 | 36·75 | 41·2 | 13 3/4 | 20 5/8 | 22 1/8 | 23 5/8 | 6 7/8 | 18·3 |
| 15/16 | 5 5/8 | 3 3/8 | 9/16 | 1 1/2 | 42·2 | 47·2 | 15·8 | 23·7 | 25·4 | 27 1/4 | 7·9 | 18·4 |
| 1 | 6 | 3 19/32 | 19/32 | 1 19/32 | 48 | 53·8 | 18 | 27 | 29 | 31·1 | 9 | 18·5 |
| 1 1/16 | 6 3/8 | 3 27/32 | 5/8 | 1 23/32 | 54·2 | 60·7 | 20·3 | 30·4 | 32 5/8 | 34·9 | 10·15 | 18·4 |
| 1 1/8 | 6 3/4 | 4 1/16 | 21/32 | 1 13/16 | 60·75 | 69 | 22 3/4 | 34 1/8 | 36·5 | 39 | 11 3/8 | 18·3 |
| 1 3/16 | 7 1/8 | 4 9/32 | 11/16 | 1 29/32 | 67·7 | 75·8 | 25 3/8 | 38 | 40·5 | 43 3/8 | 12·69 | 18·3 |
| 1 1/4 | 7 1/2 | 4 1/2 | 3/4 | 2 | 75 | 84 | 28 1/8 | 42 1/8 | 44 3/4 | 47·9 | 14 1/16 | 18·2 |
| 1 5/16 | 7 7/8 | 4 23/32 | 25/32 | 2 3/32 | 82·4 | 92 | 31 | 46·5 | 49 1/8 | 52 5/8 | 15 1/2 | 18·2 |
| 1 3/8 | 8 1/4 | 4 15/16 | 13/16 | 2 3/16 | 90·75 | 101·6 | 34 | 51 | 53 3/4 | 57·5 | 17 | 18·1 |

TABLE 219.—STUD-LINK CHAIN-CABLES (*continued*).

| Diameter of Iron. | Length of One Link, Outside. | Width of One Link, Outside. | Radius of End of Link, Inside. | Length of Stud at Crown. | Weight of 100 Fathoms. | Weight of One Fathom (Six Feet). | Statutory Proof Tensile Stress, for each 15 Fathoms separately. | Statutory Ultimate Strength or Breaking Stress, on Three Links in each 15 Fathoms. | Actual Breaking Stress. Good Ordinary Cable. | Actual Breaking Stress. High Breaking Stress. | Safe-Working Stress (Half the Proof Stress). | Ultimate or Breaking Stress per Square Inch of Good Ordinary Cable. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Inches. | Inches. | Inches. | Inch. | Inches. | Cwts. | Pounds. | Tons. | Tons. | Tons | Tons. | Tons. | Tons. |
| 1 7/16 | 8 5/8 | 5 3/16 | 27/32 | 2 5/16 | 99·5 | 111 | 37 1/8 | 55 5/8 | 58 5/8 | 62·7 | 18·56 | 18·0 |
| 1 1/2 | 9 | 5 13/32 | 7/8 | 2 13/32 | 108 | 121 | 40·5 | 58·7 | 63·6 | 68 | 20 1/4 | 18·0 |
| 1 9/16 | 9 3/8 | 5 5/8 | 29/32 | 2 1/2 | 116·8 | 131 | 43·9 | 61·4 | 68·7 | 73·6 | 22 | 17·9 |
| 1 5/8 | 9 3/4 | 5 27/32 | 15/16 | 2 19/32 | 126·75 | 142 | 47·5 | 66·5 | 74 | 79·3 | 23 3/4 | 17·8 |
| 1 11/16 | 10 1/8 | 6 3/32 | 1 | 2 23/32 | 138·7 | 152 | 51 1/4 | 71 3/4 | 79 5/8 | 85·2 | 25 1/2 | 17·8 |
| 1 3/4 | 10 1/2 | 6 5/16 | 1 1/32 | 2 13/16 | 147 | 164·6 | 55 1/8 | 77 1/8 | 85 3/8 | 91 3/8 | 27 1/2 | 17·7 |
| 1 13/16 | 10 7/8 | 6 17/32 | 1 1/16 | 2 29/32 | 158 | 176 | 59 1/8 | 82 3/4 | 91·2 | 97 5/8 | 29 1/2 | 17·7 |
| 1 7/8 | 11 1/4 | 6 3/4 | 1 3/32 | 3 | 168·75 | 189 | 63 1/4 | 88·5 | 97 1/4 | 104 1/8 | 31 5/8 | 17·6 |
| 1 15/16 | 11 5/8 | 6 31/32 | 1 1/8 | 3 3/32 | 180 | 201 | 67·5 | 94·5 | 103 1/2 | 110·8 | 33 3/4 | 17·6 |
| 2 | 12 | 7 3/16 | 1 5/32 | 3 3/16 | 192 | 215 | 72 | 100·8 | 109·9 | 117 5/8 | 36 | 17·5 |
| 2 1/16 | 12 3/8 | 7 7/16 | 1 7/32 | 3 5/16 | 203 | 228 | 76·5 | 107·1 | 116·4 | 124·5 | 38 1/4 | 17·4 |
| 2 1/8 | 12 3/4 | 7 21/32 | 1 1/4 | 3 13/32 | 216·75 | 242·8 | 81 1/4 | 113 3/4 | 123 1/8 | 131·9 | 40 5/8 | 17·3 |
| 2 3/16 | 13 1/8 | 7 7/8 | 1 9/32 | 3 1/2 | 229 | 259 | 86 1/8 | 120·5 | 130·1 | 139 1/4 | 43 | 17·3 |
| 2 1/4 | 13 1/2 | 8 3/32 | 1 5/16 | 3 19/32 | 243 | 276·2 | 91 1/8 | 127·5 | 137 1/8 | 146 3/4 | 45 1/2 | 17·2 |
| 2 5/16 | 13 7/8 | 8 11/32 | 11/32 | 3 23/32 | 256 | 289 | 96 1/4 | 134 3/4 | 144 1/4 | 154 1/2 | 48 1/8 | 17·2 |
| 2 3/8 | 14 1/4 | 8 9/16 | 1 3/8 | 3 13/16 | 270·75 | 303·2 | 101·5 | 142·1 | 151 5/8 | 162·4 | 50 3/4 | 17·1 |
| 2 7/16 | 14 5/8 | 8 25/32 | 1 13/32 | 3 29/32 | 285 | 319 | 106·9 | 149 5/8 | 159·2 | 170·4 | 53 1/2 | 17·1 |
| 1/2 | 15 | 9 | 1 15/32 | 4 | 300 | 336 | 112·5 | 157·5 | 166 7/8 | 178 5/8 | 56 1/4 | 17·0 |

TABLE 220.—SHORT-LINK OR UNSTUDDED CHAIN-CABLES: DIMENSIONS, WEIGHT, AND STRENGTH.

| Diameter of Iron. | Length of One Link, Outside. | Width of One Link, Outside. | Radius of End of Link, Inside. | Weight of One Fathom (Six Feet). | Statutory Proof Tensile Stress, for each 15 Fathoms separately. | Statutory Breaking Stress, or Ultimate Strength, in Three Links in each 15 Fathoms. | Actual Breaking Stress. | | Safe-Working Stress (Half the Proof Stress). | Ultimate Breaking Stress per Sq. Inch of Good Ordinary Cable. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Good Ordinary Cable. | High Breaking Stress. | | |
| Inches. | Inches. | Inches. | Inch. | Pounds. | Tons. | Tons. | Tons. | Tons. | Tons. | Tons. |
| $\frac{1}{4}$ | $1\frac{7}{32}$ | $\frac{7}{8}$ | $\frac{5}{32}$ | 3·44 | $\frac{3}{4}$ | $1\frac{1}{2}$ | $1\frac{5}{8}$ | 1·7 | $\frac{3}{8}$ | 16·6 |
| $\frac{5}{16}$ | $1\frac{17}{32}$ | $1\frac{3}{32}$ | $\frac{3}{16}$ | $5\frac{1}{2}$ | $1\frac{1}{8}$ | $2\frac{1}{4}$ | 2·6 | $2\frac{5}{8}$ | $\frac{9}{16}$ | 16·8 |
| $\frac{3}{8}$ | $1\frac{27}{32}$ | $1\frac{5}{16}$ | $\frac{7}{32}$ | 8 | $1\frac{5}{8}$ | $3\frac{1}{4}$ | $3\frac{3}{4}$ | 3·9 | $\frac{13}{16}$ | 17·0 |
| $\frac{7}{16}$ | $2\frac{1}{8}$ | $1\frac{17}{32}$ | $\frac{9}{32}$ | $10\frac{1}{2}$ | $2\frac{1}{4}$ | $4\frac{1}{2}$ | $5\frac{1}{8}$ | 5·3 | $1\frac{1}{8}$ | 17·1 |
| $\frac{1}{2}$ | $2\frac{7}{16}$ | $1\frac{3}{4}$ | $\frac{5}{16}$ | $13\frac{3}{4}$ | 3 | 6 | $6\frac{3}{4}$ | 7 | $1\frac{1}{2}$ | 17·1 |
| $\frac{9}{16}$ | $2\frac{3}{4}$ | $1\frac{31}{32}$ | $\frac{11}{32}$ | 17 | $3\frac{3}{4}$ | $7\frac{1}{2}$ | $8\frac{1}{2}$ | 8·9 | $1\frac{7}{8}$ | 17·2 |
| $\frac{5}{8}$ | $3\frac{1}{16}$ | $2\frac{3}{16}$ | $\frac{3}{8}$ | 22 | $4\frac{5}{8}$ | $9\frac{1}{4}$ | $10\frac{1}{2}$ | 11 | $2\frac{5}{16}$ | 17·2 |
| $\frac{11}{16}$ | $3\frac{3}{8}$ | $2\frac{13}{32}$ | $\frac{13}{32}$ | 26 | $5\frac{5}{8}$ | $11\frac{1}{4}$ | 12·8 | 13·4 | $2\frac{13}{16}$ | 17·2 |
| $\frac{3}{4}$ | $3\frac{11}{16}$ | $2\frac{5}{8}$ | $\frac{15}{32}$ | 30 | $6\frac{3}{4}$ | $13\frac{1}{2}$ | $15\frac{1}{4}$ | 16 | $3\frac{3}{8}$ | 17·3 |
| $\frac{13}{16}$ | $3\frac{31}{32}$ | $2\frac{27}{32}$ | $\frac{1}{2}$ | 36 | 7·9 | 15·8 | 17·9 | 18·8 | 4 | 17·3 |
| $\frac{7}{8}$ | $4\frac{9}{32}$ | $3\frac{1}{16}$ | $\frac{17}{32}$ | 42 | $9\frac{1}{8}$ | $18\frac{1}{4}$ | 20·8 | $21\frac{7}{8}$ | $4\frac{9}{16}$ | 17·3 |
| $\frac{15}{16}$ | $4\frac{19}{32}$ | $3\frac{9}{32}$ | $\frac{9}{16}$ | 49 | $10\frac{1}{2}$ | 21 | 23·9 | $25\frac{1}{8}$ | $5\frac{1}{4}$ | 17·4 |
| 1 | $4\frac{29}{32}$ | $3\frac{1}{2}$ | $\frac{19}{32}$ | 55 | 12 | 24 | 27·3 | $28\frac{5}{8}$ | 6 | 17·4 |
| $1\frac{1}{16}$ | $5\frac{7}{32}$ | $3\frac{23}{32}$ | $\frac{21}{32}$ | 60 | $13\frac{1}{2}$ | 27 | 30·7 | $32\frac{1}{4}$ | $6\frac{3}{4}$ | 17·3 |
| $1\frac{1}{8}$ | $5\frac{1}{2}$ | $3\frac{15}{16}$ | $\frac{11}{16}$ | 68 | $15\frac{1}{8}$ | $30\frac{1}{4}$ | 34·3 | 36 | $7\frac{1}{2}$ | 17·2 |
| $1\frac{3}{16}$ | $5\frac{13}{16}$ | $4\frac{5}{33}$ | $\frac{23}{32}$ | 76 | 16·9 | 33·8 | $38\frac{1}{8}$ | 39·9 | $16\frac{1}{2}$ | 17·1 |
| $1\frac{1}{4}$ | $6\frac{1}{8}$ | $4\frac{3}{8}$ | $\frac{3}{4}$ | 84 | $18\frac{3}{4}$ | $37\frac{1}{2}$ | $42\frac{1}{8}$ | $44\frac{1}{8}$ | $9\frac{3}{8}$ | 17·0 |

TABLE 220.—SHORT-LINK CHAIN CABLES (*continued*).

| Diameter of Iron. | Length of One Link, Outside. | Width of One Link, Outside. | Radius of End of Link, Inside. | Weight of One Fathom (Six Feet). | Statutory Proof Tensile Stress, for each 15 Fathoms separately. | Statutory Breaking Stress, or Ultimate Strength, in Three Links in each 15 Fathoms. | Actual Breaking Stress. | | Safe-Working Stress (Half the Proof Stress). | Ultimate Breaking Stress per Sq. Inch of Good Ordinary Cable. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Good Ordinary Cable. | High Breaking Stress. | | |
| Inches. | Inches. | Inches. | Inches. | Pounds. | Tons. | Tons. | Tons. | Tons. | Tons. | Tons. |
| $1\frac{5}{16}$ | $6\frac{7}{16}$ | $4\frac{19}{32}$ | $\frac{25}{32}$ | 93 | $20\frac{5}{8}$ | $41\frac{1}{4}$ | $46\frac{1}{4}$ | $48\frac{1}{2}$ | $10\frac{1}{4}$ | 17·0 |
| $1\frac{3}{8}$ | $6\frac{3}{4}$ | $4\frac{13}{16}$ | $\frac{27}{32}$ | 102 | $22\frac{5}{8}$ | $45\frac{1}{4}$ | 50·6 | 53 | $11\frac{1}{4}$ | 17·0 |
| $1\frac{7}{16}$ | $7\frac{1}{32}$ | $5\frac{1}{32}$ | $\frac{7}{8}$ | 111 | $24\frac{3}{4}$ | $49\frac{1}{2}$ | $55\frac{1}{3}$ | 57·8 | $12\frac{3}{8}$ | 17·0 |
| $1\frac{1}{2}$ | $7\frac{11}{32}$ | $5\frac{1}{4}$ | $\frac{29}{32}$ | 120 | 27 | 54 | 59·8 | 62·7 | $13\frac{1}{2}$ | 16·9 |
| $1\frac{9}{16}$ | $7\frac{21}{32}$ | $5\frac{15}{32}$ | $\frac{15}{16}$ | 131 | $29\frac{1}{4}$ | $58\frac{1}{2}$ | $64\frac{5}{8}$ | 67·8 | $14\frac{5}{8}$ | 16·9 |
| $1\frac{5}{8}$ | $7\frac{31}{32}$ | $5\frac{11}{16}$ | 1 | 144 | $31\frac{5}{8}$ | $63\frac{1}{4}$ | 69·7 | 73 | $15\frac{3}{4}$ | 16·8 |
| $1\frac{11}{16}$ | $8\frac{9}{32}$ | $5\frac{29}{32}$ | $1\frac{1}{32}$ | 159 | $34\frac{1}{8}$ | $68\frac{1}{4}$ | 74·9 | $78\frac{1}{2}$ | 17 | 16·8 |
| $1\frac{3}{4}$ | $8\frac{11}{32}$ | $6\frac{1}{8}$ | $1\frac{1}{16}$ | 168 | $36\frac{3}{4}$ | $73\frac{1}{2}$ | 80·3 | $84\frac{1}{8}$ | $18\frac{3}{8}$ | 16·8 |
| $1\frac{13}{16}$ | $8\frac{7}{8}$ | $6\frac{11}{32}$ | $1\frac{3}{32}$ | 181 | 39·4 | 78·8 | 85·8 | 90 | $19\frac{3}{4}$ | 16·7 |
| $1\frac{7}{8}$ | $9\frac{3}{16}$ | $6\frac{9}{16}$ | $1\frac{1}{8}$ | 196 | $42\frac{1}{3}$ | $84\frac{1}{4}$ | $91\frac{1}{2}$ | 95·9 | 21 | 16·6 |
| $1\frac{15}{16}$ | $9\frac{1}{2}$ | $6\frac{25}{32}$ | $1\frac{5}{32}$ | 207 | 45 | 90 | 97·4 | 102 | $22\frac{1}{2}$ | 16·5 |
| 2 | $9\frac{13}{16}$ | 7 | $1\frac{7}{32}$ | 220 | 48 | 96 | 103·4 | $108\frac{3}{8}$ | 24 | 16·4 |
| $2\frac{1}{16}$ | $10\frac{1}{8}$ | $7\frac{7}{32}$ | $1\frac{1}{4}$ | 233 | 51 | 102 | $109\frac{5}{8}$ | 114·8 | $25\frac{1}{2}$ | 16·4 |
| $2\frac{1}{8}$ | $10\frac{13}{32}$ | $7\frac{7}{16}$ | $1\frac{9}{32}$ | 248 | $54\frac{1}{8}$ | $108\frac{1}{4}$ | 115·9 | 121·4 | 27 | 16·3 |
| $2\frac{3}{16}$ | $10\frac{23}{32}$ | $7\frac{21}{32}$ | $1\frac{5}{16}$ | 262 | 57·4 | 114·8 | 122·4 | 128·2 | $28\frac{3}{4}$ | 16·3 |
| $2\frac{1}{4}$ | $11\frac{1}{32}$ | $7\frac{7}{8}$ | $1\frac{11}{32}$ | 272 | $60\frac{3}{4}$ | $121\frac{1}{2}$ | 129 | $135\frac{1}{8}$ | $30\frac{3}{8}$ | 16·2 |
| $2\frac{5}{16}$ | $11\frac{11}{32}$ | $8\frac{3}{32}$ | $1\frac{13}{32}$ | 290 | $64\frac{1}{8}$ | $128\frac{1}{4}$ | $135\frac{3}{4}$ | $142\frac{1}{4}$ | 32 | 16·2 |
| $2\frac{3}{8}$ | $11\frac{5}{8}$ | $8\frac{5}{16}$ | $1\frac{7}{16}$ | 304 | $67\frac{5}{8}$ | $135\frac{1}{4}$ | 142·8 | 149·4 | $33\frac{3}{4}$ | 16·1 |
| $2\frac{7}{16}$ | $11\frac{15}{16}$ | $8\frac{17}{32}$ | $1\frac{15}{32}$ | 319 | $71\frac{1}{4}$ | $142\frac{1}{2}$ | $149\frac{7}{8}$ | $156\frac{7}{8}$ | $35\frac{5}{8}$ | 16·1 |
| $2\frac{1}{2}$ | $12\frac{1}{4}$ | $8\frac{3}{4}$ | $1\frac{1}{2}$ | 336 | 75 | 150 | 157 | 164·4 | $37\frac{1}{2}$ | 16·0 |

original area of section, with a reduction in length of not less than 10 per cent. The steel pins for retaining the joining shackle-bolt, are to be capable of bearing a tensile stress not less than 35 tons per square inch, with a contraction at the fracture of not less than 45 per cent. of the original area. Mooring and close-link crane and rigging chains are to be proved to a stress of 8·47 tons per square inch of section of the sides of the link, or 466 pounds per circular $\frac{1}{8}$ inch of section. Defective links are to be cut out and replaced. Stud-chain cables are to be proved according to the Act, as already described. Four-feet sample lengths of chain are to be tested for ultimate strength, which is not to be less than 16 tons per square inch of section of both sides of the links, or 880 pounds per circular $\frac{1}{8}$-inch.

The $1\frac{1}{2}$-inch mooring chain is made in lengths of 15 fathoms, with a joining shackle to each length, and a swivel for every 30 fathoms. The $1\frac{1}{4}$ inch, $1\frac{1}{8}$ inch, 1 inch, and $\frac{7}{8}$ inch mooring chains are in lengths of from 8 fathoms to 45 fathoms. Stud-chain cables are made in lengths of $12\frac{1}{2}$ fathoms. The common links of mooring chains are 6 diameters in length, the breadth is 3·5 diameters. The ordinary end link is of iron, 1·2 diameters, $6\frac{1}{2}$ diameters in length, 4·1 in breadth.

TABLE 221.—CHAIN MOORINGS, IN TEN-FATHOM LENGTHS: OPEN OR UNSTUDDED LINKS: SIZES, WEIGHT, AND PROOF-STRESS.

(Admiralty.)

| Size, or Diameter of Iron at Sides of Link. | Greater Diameter at the Ends of Link. | Weight of Ten Fathoms. | Proof-Stress. |
|---|---|---|---|
| Inches | Inches. | Cwts. | Tons. |
| $2\frac{3}{4}$ | 3·025 | 40 | 72 |
| $2\frac{7}{8}$ | 3·162 | 45 | 79 |
| 3 | 3·3 | 50 | 86 |
| $3\frac{1}{8}$ | 3·437 | 55 | 93 |
| $3\frac{1}{4}$ | 3·575 | 60 | 101 |
| $3\frac{1}{2}$ | 3·85 | 75 | 117 |
| $3\frac{3}{4}$ | 4·125 | 87 | 134 |

*Note.*—The breaking stress must be not less than 1·40 times the proof stress; that is, 40 per cent. more.

## TABLE 222.—CHAIN-RIGGING, CRANE CHAINS (SHORT LINK): SIZE AND WEIGHT.

(Admiralty.)

| Size or Diameter of Iron. | Weight of One Fathom. | Size or Diameter of Iron. | Weight of One Fathom. | Size or Diameter of Iron | Weight of One Fathom. |
|---|---|---|---|---|---|
| Inches. | Pounds. | Inches. | Pounds. | Inches. | Pounds. |
| $\frac{1}{8}$ | 2 | $\frac{9}{16}$ | 21 | $1\frac{1}{8}$ | 73 |
| $\frac{3}{16}$ | 3 | $\frac{5}{8}$ | 25 | $1\frac{1}{4}$ | 92 |
| $\frac{1}{4}$ | $4\frac{3}{4}$ | $\frac{11}{16}$ | 30 | $1\frac{3}{8}$ | 108 |
| $\frac{9}{32}$ | $5\frac{3}{4}$ | $\frac{3}{4}$ | 36 | $1\frac{1}{2}$ | 132 |
| $\frac{5}{16}$ | $6\frac{3}{4}$ | $\frac{13}{16}$ | 39 | $1\frac{5}{8}$ | 155 |
| $\frac{3}{8}$ | $9\frac{1}{2}$ | $\frac{7}{8}$ | 48 | $1\frac{3}{4}$ | 179 |
| $\frac{7}{16}$ | $13\frac{1}{4}$ | $\frac{15}{16}$ | 53 | | |
| $\frac{1}{2}$ | 17 | 1 | 61 | | |

## TABLE 223.—SHORT-LINK CHAINS: WEIGHT AND CONDITIONS OF TEST.

(India Stores Department.)

| Diameter of Iron. | Weight of One Fathom. | Proof Stress. | Load on Test Piece. | Elongation of Test Piece on Thirty-six Inches. |
|---|---|---|---|---|
| Inches. | Pounds. | Tons. | Tons. | Inches. |
| $\frac{1}{8}$ | 1 | $\frac{3}{16}$ | $\frac{7}{16}$ | 6 |
| $\frac{3}{16}$ | $2\frac{1}{4}$ | $\frac{2}{5}$ | 1 | 7 |
| $\frac{1}{4}$ | $3\frac{3}{4}$ | $\frac{3}{4}$ | $1\frac{3}{4}$ | $8\frac{1}{4}$ |
| $\frac{5}{16}$ | 6 | $1\frac{1}{8}$ | 3 | $9\frac{1}{4}$ |
| $\frac{3}{8}$ | $8\frac{1}{2}$ | $1\frac{5}{8}$ | $4\frac{1}{4}$ | $8\frac{5}{8}$ |
| $\frac{7}{16}$ | $11\frac{1}{2}$ | $2\frac{1}{4}$ | $5\frac{3}{4}$ | $8\frac{3}{4}$ |
| $\frac{1}{2}$ | 15 | 3 | 7 | $7\frac{1}{8}$ |
| $\frac{9}{16}$ | 19 | $3\frac{3}{4}$ | $8\frac{1}{2}$ | $8\frac{1}{4}$ |
| $\frac{5}{8}$ | $23\frac{1}{2}$ | $4\frac{5}{8}$ | $11\frac{3}{4}$ | 10 |
| $\frac{11}{16}$ | $28\frac{1}{2}$ | $5\frac{5}{8}$ | $13\frac{3}{4}$ | $8\frac{1}{4}$ |
| $\frac{3}{4}$ | 34 | $6\frac{3}{4}$ | $16\frac{1}{4}$ | $9\frac{1}{4}$ |
| $\frac{13}{16}$ | 40 | 7·9 | $18\frac{3}{4}$ | $9\frac{3}{4}$ |
| $\frac{7}{8}$ | 46 | $9\frac{1}{8}$ | 22 | $8\frac{7}{8}$ |
| $\frac{15}{16}$ | 53 | $10\frac{1}{2}$ | $24\frac{1}{2}$ | $8\frac{3}{8}$ |
| 1 | 60 | 12 | 29 | $8\frac{7}{16}$ |
| $1\frac{1}{8}$ | 76 | $15\frac{1}{8}$ | $36\frac{1}{4}$ | $8\frac{5}{8}$ |
| $1\frac{1}{4}$ | 94 | $18\frac{3}{4}$ | $41\frac{3}{4}$ | $9\frac{3}{4}$ |
| $1\frac{3}{8}$ | 114 | $22\frac{5}{8}$ | $51\frac{3}{4}$ | $10\frac{5}{8}$ |
| $1\frac{1}{2}$ | 135 | 27 | 64 | $11\frac{3}{8}$ |

## FRAMING.

### Cranes.

When a crane *abc*, fig. 72, is loaded at *c* by the weight W, the stresses in the three members *ab*, *ac*, and *bc*, due to the load, are measured proportionally by the respective lengths of

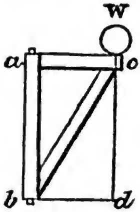



FIG. 72.—Crane.

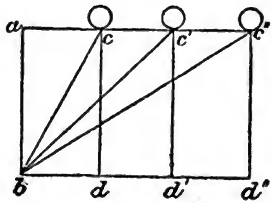



FIG. 73.—Crane.

these members; the vertical stress in the member *ab*, being equal to the load W. The diagonal and horizontal stresses increase with the overhang, as shown in fig. 73, by the increasing lengths of the diagonal and horizontal members, *bc*″, &c., and *ac*″, &c.; the vertical *ab* being constant.

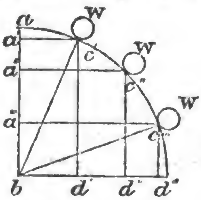



FIG. 74.—Crane.

Again, the diagonal stress increases proportionally with the obliquity of the jib *bc*″, &c., fig. 74, taken as constant in length.

Where both the diagonal and the tie member are oblique, as *bc* and *ac*, fig. 75, the stresses in the triangular figure, *abc*, as before, are measured proportionally by the lengths of the members; *ab* being the measure of the load W. The horizontal pull at *a*, is measured by the horizontal length *ac*′.

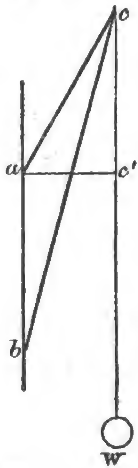



FIG. 75.—Crane.

### Truss.

The truss or triangular frame *abc*, fig. 76, having equal limbs, *ac*, *bc*, supports the load W at the apex. In the parallelogram *acbe*, *ce* is the weight, *cd* is half the weight, and *ca* and *cb* are oblique compressive stresses. The horizontal tensional stress in *ab*

is equal to the product of the weight by the span, divided

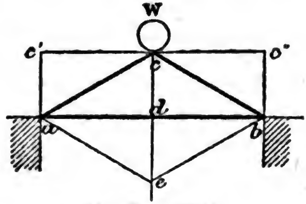



FIG. 76.—Truss.

by 4 times the rise. The horizontal thrust at the apex is equal to the tension in *ab*.

## Framed Girders.

The tensional stress, or unit stress, in the extreme horizontal members *aa'* and *b'b*, fig. 77, showing a Warren girder, is equal to ·2885 W, in which W is the load at the centre. The stress, whether tensional or compressive, on any bay is equal to the product of the unit-stress by the order-number of

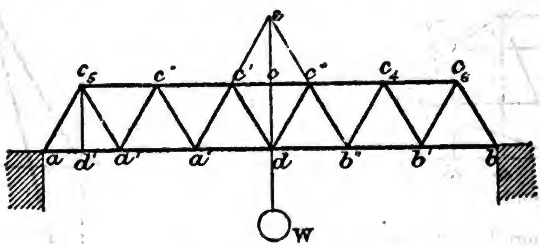



FIG. 77.—Warren Girder.

the bay; above or below, reckoned from the extreme bay as 1, towards the middle. The stress on the central bay, also, is equal to the product of the unit-stress by $\frac{n+1}{2}$, in which $n$ is the total number of bays. The stress on the middle pair of bays, tensional or compressive, is equal to the product of the unit-stress by $\frac{n-1}{2}$. In fig. 44, the stress on the central bay $c'c''$, is 1·731 W; in the central pair, it is 1·443 W. The stress in the braces is ·577 W, or twice the unit-stress in the flange.

**Truss Roofs.**

In the ordinary triangular roof truss, *abc*, fig. 78, in which the total weight, including the load, is uniformly distributed, the tension in the horizontal member *ab*, is equal to $\frac{Wl}{8d}$, or the product of the weight by the span, divided by 8 times the rise. The horizontal thrust at the ridge *c* is equal to the tension in the horizontal tie.

When the horizontal tie, *ab*, is applied at any higher level, the tension in it is increased inversely as the depth *cd*.

In the A roof truss, fig. 45, there are two trusses, each of which goes to form half the roof, and the horizontal tierod E. Let the span *ab* be 40 feet, the rise 10 feet, and the depth *cd* 8 feet. The rafters *ac* and *bc* are 22·5 feet long; the struts F are 3·33 feet long, the tension bars C and D are 11·75 feet long. The weight on the couple is 8 tons, uniformly distributed, of which 4 tons is supported on each rafter, say 1 ton at *a*, the abutment, 2 tons at F, and 1 ton at the ridge *c*. The

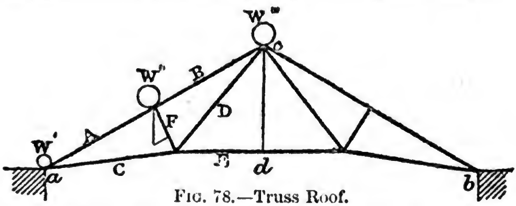



FIG. 78.—Truss Roof.

pressure at F, 2 tons, being vertical, is resolved, as indicated by diagram, into 1·8 tons stress on F, and ·875 tons on A. The stress on F is resolved into 3·18 tons on each of the tie-rods C and D. The tension in E is by formula $\frac{Wl}{8d}$, equal to $\frac{8 \times 40}{8 \times 8}$ = 5 tons, which is resolved into $4\frac{3}{4}$ tons in C, and ·875 ton in F. This tension in F is resolved into 1·54 tons in each of C and D. Summing up the tensile stresses, there are (3·18 + 4·75 + 1·54 =) 9·47 tons in C; (3·18 + 1·54 =) 4·72 tons in D; and 5 tons in E.

## HARDNESS OF METALS, ALLOYS, AND STONES.

Messrs. F. Crace Calvert and R. Johnson tested the comparative hardness of metals by the indentation made by a steel point under pressure. The steel point was about $\frac{1}{4}$ inch long, $1\frac{1}{4}$ millimetres or ·049 inch wide at the point. Weights wer added until the point entered to the extent of $3\frac{1}{2}$ millim or ·128 inch in the course of half an hour. The Table 224

the comparative hardness of several metals; and Table 225 gives the result for several alloys of copper, zinc, tin, lead, and antimony. The highest degree of hardness is that of cast iron, and it is, for the purpose of comparison, taken as 1000.

In the last column of the Table of alloys, the degree of hardness is calculated in terms of the elements separately, for simple mixtures.

The results from the alloys of copper and zinc, Table 225, No. 1, show that all the alloys having excess of copper are much harder than the metals composing them; and that increase of hardness is due to the zinc, the softer metal. But, if the zinc exceeds in proportion fifty per cent. of the alloy, the alloy becomes so brittle as to break as the point penetrates. The alloy Zn Cu, consisting of equal weights of copper and zinc, is remarkable for its hardness, which is about three times the calculated degree of hardness.

In section 4, of Table 225, may be noted the softness of the bronze with excess of tin. Also, that an increase of quantity of so malleable a metal as copper should so suddenly render the alloy brittle, until for Sn $Cu^{10}$, brittleness ceases, and the hardness is nearly equal to that of wrought iron.

In section 5, Table 225, it is notable that the calculated hardness of alloys of tin and zinc, is not very different from the actual hardness: indicating a state of simple mixture of the elements.

In Table 226, is given the comparative hardness of granites and other stones according to M. Reynaud.

TABLE 224.—COMPARATIVE HARDNESS OF METALS.
(F. Crace Calvert & R. Johnson.)

| Metal. | Comparative Hardness Cast Iron = 1000. |
|---|---|
| Cast Iron, Staffordshire cold-blast, grey, No. 3 . . . . . . . . . | 1000 |
| Steel . . . . . . . . . . | 958 |
| Wrought Iron (made from above cast iron) . . . . . . . . . | 948 |
| Platinum . . . . . . . . . | 375 |
| Copper, pure . . . . . . . . . | 301 |
| Aluminium . . . . . . . . . | 271 |
| Silver, pure . . . . . . . . . | 208 |
| Zinc, ,, . . . . . . . . . | 183 |
| Gold, ,, . . . . . . . . . | 167 |
| [illegible]mium, pure . . . . . . . . | 108 |
| [illegible]h, ,, . . . . . . . . . | 52 |
| [illegible] ,, . . . . . . . . . | 27 |
| [illegible] ,, . . . . . . . . . | 16 |

TABLE 225.—COMPARATIVE HARDNESS OF ALLOYS.

| ALLOYS. | Proportions per cent., by Weight. | Comparative Hardness. Cast Iron =1000. | Calculated Hardness. Cast Iron =1000. |
|---|---|---|---|
| 1. *Copper and Zinc.* | | | |
| Zn Cu⁵ . . . | C 82·95<br>Z 17·05 | 427 | 281 |
| Zn Cu⁴ . . | C 79·56<br>Z 20·44 | 469 | 277 |
| Zn Cu³ . . . | C 74·48<br>Z 25·52 | 469 | 276 |
| Zn Cu² . . | C 66·06<br>Z 33·94 | 473 | 261 |
| Zn Cu . . . | C 49·32<br>Z 50·68 | 604 | 243 |
| Cu Zn² . . | C 32·74<br>Z 67·26 | Broke | ... |
| Cu Zn³ . . . | C 24·64<br>Z 75·36 | " | ... |
| Cu Zn⁴ . . | C 19·57<br>Z 80·43 | " | ... |
| Cu Zn⁵ . . . | C 16·30<br>Z 83·70 | " | ... |
| 2. *Lead & Antimony.* | | | |
| Pb Sb⁵ . . | L 24·31<br>A 75·69 | Broke | ... |
| Pb Sb⁴ . . . | L 28·64<br>A 71·36 | " | ... |
| Pb Sb³ . . | L 34·86<br>A 65·14 | ... | ... |
| Pb Sb² . . . | L 44·53<br>A 55·47 | ... | ... |
| Pb Sb . . | A 38·39<br>L 61·61 | ... | ... |
| Pb Sb² . . . | A 23·68<br>L 76·32 | ... | ... |
| Pb Sb³ . . | A 17·20<br>L 82·80 | ... | ... |
| Pb Sb⁴ . . . | A 13·48<br>L 86·52 | ... | ... |
| Pb Sb⁵ . . | A 11·08<br>L 88·92 | ... | ... |

TABLE 225.—COMPARATIVE HARDNESS OF ALLOYS (*cont.*).

| ALLOYS. | Proportions per cent., by Weight. | Comparative Hardness. Cast Iron =1000. | Calculated Hardness. Cast Iron =1000. |
|---|---|---|---|
| 3. *Commercial Brasses.* | | | |
| "Large bearings" | Copper 82·05<br>Tin 12·82<br>Zinc 5·13 | 562 | 259 |
| Mud plugs . . | Copper 80<br>Tin 10<br>Zinc 10 | 750 | 262 |
| Yellow brass . . | Copper 64<br>Zinc 56 | 520 | 258 |
| Pumps and pipes. | Copper 80<br>Tin 5<br>Zinc 7·5<br>Lead 7·5 | 343 | 257 |
| 4. *Copper and Tin (Bronze).* | | | |
| $Cu\,Sn^5$ . . . | C 9·73<br>T 90·27 | 83 | 52 |
| $Cu\,Sn^4$ . . | C 11·86<br>T 88·14 | 96 | 60 |
| $Cu\,Sn^3$ . . . | C 15·21<br>T 84·79 | 104 | 69 |
| $Cu\,Sn^2$ . . | C 21·21<br>T 78·79 | 135 | 85 |
| Cu Sn . . . | C 34·98<br>T 65·02 | Broke | ... |
| $Sn\,Cu^2$ . . | T 51·83<br>C 48·17 | " | ... |
| $Sn\,Cu^3$ . . . | T 38·29<br>C 61·79 | " | ... |
| $Sn\,Cu^4$ . . | T 31·73<br>C 68·27 | " | ... |
| $Sn\,Cu^5$ . . . | T 27·10<br>C 72·90 | " | ... |
| $Sn\,Cu^{10}$ . . | T 15·68<br>C 84·32 | 917 | 257 |
| $Sn\,Cu^{15}$ . . . | T 11·03<br>C 88·97 | 773 | 271 |
| $Sn\,Cu^{20}$ . . | T 8·51<br>C 91·49 | 640 | 278 |
| [illegible] $Cu^{25}$ . . . | T 6·83<br>C 98·17 | 602 | 279 |

TABLE 225.—COMPARATIVE HARDNESS OF ALLOYS (*cont.*).

| ALLOYS. | Proportions per cent., by Weight. | Comparative Hardness. Cast Iron =1000. | Calculated Hardness. Cast Iron =1000. |
|---|---|---|---|
| 5. *Tin and Zinc.* | | | |
| $Zn\,Sn^2$ . . . | Z 21·65<br>T 78·35 | 65 | 61 |
| $Zn\,Sn$ . . | Z 35·60<br>T 64·40 | 69 | 83 |
| $Sn\,Zn^2$ . . . | Z 47·49<br>T 52·51 | 83 | 110 |
| $Sn\,Zn^3$ . . | Z 37·57<br>T 62·43 | 94 | 125 |
| $Sn\,Zn^4$ . . . | Z 31·14<br>T 68·86 | 105 | 131 |
| $Sn\,Zn^5$ . . | Z 26·57<br>T 73·43 | 125 | 142 |
| $Sn\,Zn^6$ . . . | Z 15·32<br>T 84·68 | 121 | 158 |
| 6. *Lead and Tin.* | | | |
| $Pb\,Sn^5$ . . . | L 26·03<br>T 73·97 | 42 | 24 |
| $Pb\,Sn^4$ . . | L 30·57<br>T 69·43 | 41 | 24 |
| $Pb\,Sn^3$ . . . | L 36·99<br>T 63·01 | 32 | 23 |
| $Pb\,Sn^2$ . . | L 46·82<br>T 53·18 | 26 | 20 |
| $Pb\,Sn$ . . . | L 63·78<br>T 36·22 | 21 | 20 |
| $Sn\,Pb^2$ . . | T 22·11<br>L 77·89 | 26 | 18 |
| $Sn\,Pb^3$ . . . | T 15·91<br>L 84·09 | 21 | 17 |
| $Sn\,Pb^4$ . . | T 12·43<br>L 87·57 | 26 | 17 |
| $Sn\,Pb^5$ . . . | T 10·20<br>L 89·80 | 23 | 17 |

## Table 226.—Comparative Hardness of Stones.
(Reynaud.)

| Stone. | Comparative Hardness: White-veined Marble = 1. |
|---|---|
| White-veined marble . . . . . . . | 1·00 |
| Syenite (red granite) . . . . . . | 10·08 |
| Green granite . . . . . . . . | 9·70 |
| Granite (deadleaf) . . . . . . . | 9·30 |
| Grey granite of the Vosges . . . . . | 8·92 |
| " " Bretagne . . . . . | 8·56 |
| " " Normandy . . . . . | 7·00 |
| Dark grey marble . . . . . . . | 1·28 |
| Lias limestone . . . . . . . . | ·88 |

The following scale of hardness is that adopted by the Technical High School at Prague. The substances are arranged in ascending order, from the softest to the hardest. The test is made by drawing a conically pointed cylindrical piece of one of the metals tabulated along a polished surface of the metal to be tested. If the pointed pieces become blunted without marking the surface, the metal under test is harder than the pointed pieces employed. If neither point nor metal surface be abraded, the hardness is taken as equal. If the surface be scratched, the metal under test is taken as softer than the pointed metal :—

1. Pure soft lead.
2. Pure tin.
3. Pure hard lead.
4. Pure annealed copper.
5. Fine cast copper.
6. Soft bearing metal (copper, 85 ; tin, 10 ; zinc, 5).
7. Cast iron (annealed).
8. Fibrous wrought iron.
9. Fine grained light grey cast iron.
10. Toughened cast iron (melted with 10 per cent. of wrought-iron turnings).
11. Soft ingot iron, having ·15 per cent. of carbon (will not harden).
12. Steel, having ·45 per cent. of carbon (not hardened).
13. Steel, having ·96 per cent. of carbon (not hardened).
14. Crucible cast steel, hardened and tempered blue.
15. Crucible steel, hardened and tempered violet to orange-yellow.

16. Crucible steel, hardened and tempered straw-yellow.
17. Hard bearing metal (copper 83, tin 17).
18. Crucible steel, glass hard.

## LABOUR OF ANIMALS.

*Men.*—The average net daily work of an ordinary labourer at a pump, a winch, or a crane, may be taken at 3,300 foot-pounds per minute, for 8 hours a day. But, for shorter periods, from four to five times the rate may be exerted.

*Horses and Bullocks.*—Boulton and Watt estimated that a dray-horse could exert a power of 33,000 foot-pounds per minute, for 8 hours a day. Rennie's estimate of the average work of horses, strong and weak, was at the rate of 22,000 foot-pounds per minute for 8 hours a day.

A pair of well-fed bullocks can raise water at the rate of 8,000 foot-pounds per minute, for a morning's work of 4½ hours.

## MECHANICAL PRINCIPLES.

THE statical *moment* of a force or of a body, with respect to a given point, or axis, or plane, is expressed by the product of the weight of the body by its perpendicular distance from the point, axis, or plane.

In *levers*, the moment of the weight or resistance about the fulcrum, is equal to the moment of the power or force applied to counteract the resistance. Let $P$ = the power, $W$ = the weight or resistance, $L$ and $l$ respectively the lengths of the arms of the lever, taken as straight, then

$$\text{the moment } P \times L = \text{the moment } W \times l,$$

and any one of the four quantities $P$, $L$, $W$, and $l$, can be found by a simple adaptation of the above equation, thus :—

$$P = \frac{W \times l}{L} \quad . \quad . \quad . \quad . \quad . \quad (1)$$

$$W = \frac{P \times L}{l} \quad . \quad . \quad . \quad . \quad . \quad (2)$$

$$L = \frac{W \times l}{P} \quad . \quad . \quad . \quad . \quad . \quad (3)$$

$$l = \frac{P \times L}{W} \quad . \quad . \quad . \quad . \quad . \quad (4)$$

In these equations, it is assumed that the power and resistance act on the lever at right angles to it. If the lever be bent, or if the forces act obliquely, equilibrium or equality of moments may be maintained. Draw a horizontal line through the fulcrum to meet the vertical lines through the power and the weight. The moments of the power and the weight are calculated on the horizontal lengths, and they are equal to each other.

If two or more levers are connected consecutively one to the other, as one system, and the power and the weight are applied at the two extremes, in equilibrium, the power is to the weight as the compound inverse ratio of the levers. Suppose, for instance, the arms of the levers are successively as 3 to 1, 4 to 1, and 5 to 1, the compound ratio is the product of the three ratios, or it is as $(3 \times 4 \times 5 =)$ 60 to 1; and the power is to the weight as 1 to 60.

In simple *pulleys* on fixed bearings, there is no leverage, or augmentation of force; they simply transmit power, or change its direction. They act as levers having arms of equal lengths. But the pulley may be employed so as to augment the leverage, by suspending the weight to the axis of the pulley, and fixing one end of the cord, and pulling at the other end. The leverage is as 2 to 1, in this case: the weight acting at the length of the radius of the pulley from the fixed cord, and the power at the length of the diameter.

Pulleys may be combined in a pair of blocks, or sets of two or more on one axis; of which one block is fixed in position, and the other is moveable, taking the weight. The rope is usually fixed by one end to the stationary block, and is passed over the fast and moveable pulleys successively, the power being applied to the loose end. The force required at the loose end of the rope to balance the weight, irrespective of frictional and other external resistances, is equal to the quotient of the weight divided by the number of ropes by which it is carried, or the ropes proceeding from the moveable block. This number is equal to twice the number of moveable pulleys.

Conversely, to find the weight or resistance that will be balanced by a given power, irrespective of external resistances, multiply the power by the number of ropes proceeding from the moveable block.

When the fixed end of the rope is fastened to the moveable block, the divisor or multiplier is equal to twice the number of moveable pulleys plus 1.

The *wheel and axle* resemble two pulleys on one axis, having different diameters. If a weight be lifted by means of a rope wound over the axle or a roller on the axle, the

power being applied at the rim of the wheel, the action is like that of a lever of which the shorter arm is equal to the radius of the axle plus half the thickness of the rope ; and the longer arm is equal to the radius of the wheel. The power and the weight are to each other as the radial lengths inversely, irrespective of external resistance ; or they are as the diameters inversely. As with the lever, so with the wheel and axle,

$$\text{the moment } P \times L = \text{the moment } W \times l,$$

in which P is the power or force at the circumference of the wheel, W the weight on the axle or barrel, and $L \times l$ respectively the radii of the wheel and the axle. Where,

$$P = \frac{W \times l}{L} \quad . \quad . \quad . \quad . \quad (5)$$

$$W = \frac{P \times L}{l} \quad . \quad . \quad . \quad . \quad (6)$$

*On the inclined plane*, if a weight be raised by a force applied parallel to the plane, the sides of the triangle formed by the plane, its base, and its height, are proportional respectively to the weight, the pressure of the weight on the plane, and the power applied.

Let $l$ be the length of an inclined plane, and $h$ the height P the power, and W the weight drawn up the plane.

$$P = \frac{Wh}{l} \quad . \quad . \quad . \quad . \quad (7)$$

$$W = \frac{Pl}{h} \quad . \quad . \quad . \quad . \quad . \quad (8)$$

When the raising force is applied to the weight in a direction parallel to the base, the plane, its base, and its height are proportional respectively to the pressure of the weight on the plane, the weight, and the power applied.

The *wedge* is a pair of inclined planes united by their bases. The wedge is employed for the purpose of forcibly separating two bodies, or breaking or splitting a body ; or for fastening bodies together. In the application of pressure to the head or butt-end of the wedge, to cause it to penetrate a resisting body, the power is to the resistance as the thickness of the wedge is to its length. Let $t$ be the thickness, $l$ the length, W the resistance, and P the power or pressure on the head of the wedge. Then,—

$$P = \frac{Wt}{l} \quad . \quad . \quad . \quad . \quad . \quad (9)$$

$$W = \frac{Pl}{t} \quad . \quad . \quad . \quad . \quad . \quad . \quad (10)$$

The *screw* is an inclined plane lapped round a cylinder. The effect of a screw is reckoned in terms of the pitch or height of the plane for one revolution, and the radius of the handle or wheel by which it is turned. The power applied at the end of the radius describes, for one turn of the screw, a circle of which the diameter is twice the radius. The circumference of the circle is equal to 6·28 times the radius, and the power is to the resistance as the pitch of the screw is to 6·28 times the radius of the power, or to 3·14 times the diameter. Let $p$ be the pitch of the screw-thread, $r$ the radius of the lever or wheel by which the power is applied, W the weight, load, or resistance on the screw, and P the power. Then,

$$6{\cdot}28\ Pr = Wp \quad . \quad . \quad . \quad . \quad (11)$$

$$P = \frac{Wp}{6{\cdot}28r} \quad . \quad . \quad . \quad . \quad . \quad (12)$$

$$W = \frac{6{\cdot}28\,Pr}{p} \quad . \quad . \quad . \quad . \quad (13)$$

$$p = \frac{6{\cdot}28\,Pr}{W} \quad . \quad . \quad . \quad . \quad . \quad (14)$$

$$r = \frac{Wp}{6{\cdot}28\,P} \quad . \quad . \quad . \quad . \quad (15)$$

If the power be applied through a wheel, the diameter of the wheel may be substituted for the radius, when half the co-efficient—3·14—is to be employed in the formulæ.

The relations are the same whether the nut be turned upon the screw, or the screw be turned within the nut.

### Mechanical Centres.

There are various mechanical centres in solid or quasi-solid bodies—the centre of gravity, the centre of gyration, the centre of oscillation. The first is statical; the second and third are dynamical, inasmuch as these are only developed in bodies in motion.

### Centre of Gravity.

The centre of gravity of a body is that point within the body about which the gravitation of the particles of the body is self-balanced. It is a resultant centre of action, at which the body may be supposed to be concentrated: at which it can be freely supported or suspended in any position in a state of rest. In various classes of calculation the whole weight or mass of a body is taken as massed at the centre of gravity when at rest, or when in motion rectilineally.

The centre of gravity of regular plane figures or solids—as, for instance, a straight line, a square, a parallelogram, a regular polygon, a circle, the circumference of a circle, an ellipse, a prism, a cylinder, a ring, a sphere, a spheroid, a regular solid—is the same as the geometrical centre.

The centre of gravity of a plane triangle is found by drawing a straight line from one of the angles to the middle of the opposite side, and setting off one-third of this line from the side. Or, drawing two such straight lines from two of the angles, their intersection is the centre of gravity.

The centre of gravity of a trapezium is found by drawing the diagonals, and joining the centres of each alternate pair of triangles so formed. The final intersection is the centre of gravity.

In a cone or a pyramid, the centre of gravity is in the axis, at a distance of one-fourth of its length from the base.

For an arc of a circle, multiply the bisecting radius by the chord of the arc, and divide by the length of the arc. The quotient is the distance of the centre of gravity from the centre of the circle.

For a segment of a circle, cube the chord and divide by 12 times the area of the segment. The quotient is the distance of the centre of gravity from the centre of the circle.

In a sector of a circle, the centre of gravity is two-thirds of the distance of that of an arc, from the centre of the circle. Or, multiply the radius by twice the chord of the arc, and divide by three times the length of the arc; the quotient is the distance of the centre of gravity from the centre of the circle.

In a semicircle, multiply the radius by ·4244; the product is the distance of the centre of gravity from the centre of the circle.

In a solid hemisphere, the centre of gravity is at a distance of three-eighths of the radius from the centre.

For a solid spherical segment, deduct half the versed sine from the radius, and square the difference; multiply this square by the square of the versed sine and by 3·1416; and divide by the content of the segment. The quotient is the distance of the centre of gravity from the centre of the segment.

In a hemispherical surface, spherical-segment surface, or spherical-zone surface, the centre of gravity is at half the height of the axis.

In a parabola, the centre of gravity is in the axis, at a distance of three-fifths of the height from the vertex.

In a semiparabola, the centre of gravity is at the same

height as in a parabola, but it is situated at a distance from the axis, of three-eighths of the semibase.

In a paraboloid, the centre of gravity is in the axis, at a distance of two-thirds of the axis from the vertex.

For two bodies, fixed one at each end of a straight bar, the common centre of gravity is in the bar, at that point which divides the distance between their respective centres of gravity in the inverse ratio of the weights. In this solution, the weight of the bar is not reckoned for. But it may be taken as a third body, and allowed for as in the following directions.

For more than two bodies connected in one system, find the common centre of gravity of two of them; and find the common centre of these two jointly with a third body, and so on to the last body of the group.

For any plane figure, the centre of gravity may be found mechanically, by suspending the figure by any point near its edge, and marking on it the direction of a plumb-line hung from that point; then suspending it from some other point near the edge, and again marking the direction of the plumb-line. The intersection of the directions is the centre of gravity.

## Centre of Gyration.

The centre of gyration, revolution, or whirling, is the resultant centre of the force or work accumulated in the revolving mass; so situated that if all parts of the body were concentred there, the work accumulated in the body, at the same angular speed, would be the same as in the original body. To find the position of this point, the centre of gyration, suppose the revolving body to consist of an indefinitely great number of equal particles; as the work accumulated in each particle is proportional to the square of its velocity, and as the velocity is proportional to the radius of revolution, or distance of the particle from the axis of revolution, the work in each particle is proportional to the square of its distance from the axis. Multiply the weight of each particle by the square of its distance from the axis: the product is the moment of inertia of the particle, and the sum of all the products is the moment of inertia of the whole mass. Divide the moment of inertia by the weight of the body; the quotient is the square of the radius of gyration, or of the distance of the resultant centre of gyration from the axis; and the square root of the quotient is the radius of gyration. The moment of inertia is usually represented by the symbol I. Let the total revolving weight equal $w$, and the radius of gyration

equal $r$. The relations of these quantities are expressed thus :—

$$I = wr^2 \quad . \quad . \quad . \quad . \quad . \quad (16)$$

$$\frac{I}{w} = r^2 \quad . \quad . \quad . \quad . \quad . \quad (17)$$

$$r = \sqrt{\frac{I}{w}} \quad . \quad . \quad . \quad . \quad (18)$$

Concisely expressed thus :—

*The moment of inertia* is equal to the product of the weight by the square of the radius of gyration.

*The moment of inertia divided by the weight* is equal to the square of the radius of gyration.

*The radius of gyration* is equal to the square root of the quotient of the moment of inertia divided by the weight.

In calculating the radius of gyration, it is advisable in practice to divide the body into a considerable number of small parts—the more numerous the more nearly exact is the result. When these parts are equal, the radius of gyration may be determined by simply taking the mean of all the squares of the distances of the parts from the axis of revolution, and finding the square root of the mean square.

The radius of gyration of a straight bar, revolving about one end, is equal to the length of the bar multiplied by ·5773.

That of a thin rectangular plate revolving facewise on one of its edges, is equal to the radial length of the plate multiplied by ·5773.

That of a straight bar or a thin rectangular plate, revolving about its mid-length or centre, is equal to the length multiplied by ·2886.

That of a straight bar or a thin rectangular plate revolving on any point between the extremities, is, generally, equal to $\sqrt{\frac{a^3 + b^3}{3(a+b)}}$, in which $a$ and $b$ are the lengths of the two parts of the bar or plate. That is to say, divide the sum of the cubes of the two sub-lengths, by three times the length of the bar ; the square root of the quotient is equal to the radius of gyration.

That of a circular plate, a solid wheel of uniform thickness, or a solid cylinder of any length, revolving on its axis, is equal to the geometrical radius multiplied by ·7071.

That of a flat ring or hollow cylinder revolving on its axis, is equal to $\sqrt{\frac{R^2 + r^2}{2}}$, in which R and $r$ are the outer and inner geometrical radii of the ring. That is to say, the radius

of gyration is equal to the square root of half the sum of the squares of the inner and outer radii.

That of the circumference of a circle revolving about its axis, is equal to the geometrical radius.

That of the circumference of a circle revolving about a diameter, is equal to the geometrical radius of the circle multiplied by ·7071.

That of a very thin circular plate revolving about one of its diameters, is equal to half the geometrical radius of the circle.

That of a solid cylinder revolving on a diameter at mid-length, is equal to $\sqrt{\frac{l^2}{12}+\frac{r^2}{4}}$, in which $l$ and $r$ are the length and the geometrical radius respectively. That is to say, divide the square of the length by 12, and the square of the radius by 4; the radius of gyration is equal to the square root of the sum of the quotients.

That of a hollow cylinder revolving on a diameter at mid-length is equal to $\sqrt{\frac{l^2}{12}+\frac{R^2+r^2}{4}}$, in which $l$, R, and $r$, are the length, and the outer and the inner geometrical radius respectively. That is to say, divide the square of the length by 12, and the sum of the squares of the inner and outer radii by 4; the radius of gyration is equal to the square root of the sum of these two quotients.

That of a very thin hollow cylinder revolving on a diameter at mid-length, is equal to $\sqrt{\frac{l^2}{12}+\frac{R^2}{2}}$, in which $l$ and R are the length and the outer geometrical radius of the cylinder respectively. That is to say, divide the square of the length by 12, and the square of the radius by 2; the radius of gyration is equal to the square root of the sum of the quotients.

That of a solid sphere revolving about a diameter, is equal to the geometrical radius of the sphere multiplied by ·6325.

That of a hollow sphere revolving about a diameter is equal to $\sqrt{\frac{2(R^5-r^5)}{5(R^3-r^3)}}$, in which R and $r$ are the outer and inner geometrical radii respectively. That is to say, divide twice the difference of the fifth powers of the radii by five times the difference of the cubes of the radii; the radius of gyration is equal to the square root of the quotient.

That of the surface of a sphere, or a very thin hollow sphere, revolving about a diameter, is equal to the geometrical radius of the sphere multiplied by ·8165.

That of a solid cone revolving about its axis is equal to the geometrical radius of the base multiplied by ·5477.

That of a solid cone revolving about its vertex is equal to $\sqrt{\frac{12l^2+3r^2}{20}}$, in which $l$ is the length, and $r$ is the geometrical radius of the base. That is to say, to 12 times the square of the length add 3 times the square of the radius; divide the sum of these by 20; the radius of gyration is equal to the square root of the quotient.

When the cone is right-angled—the radius of the base being equal to the length,—the radius of gyration is equal to the length multiplied by ·8660.

That of a paraboloid revolving on the axis is equal to the geometrical radius of the base multiplied by ·5773.

That of a parallelopiped revolving in its own plane about one of the ends at a point midway of its breadth, is equal to $\sqrt{\frac{4l^2+b^2}{12}}$, in which $l$ is the length, and $b$ the breadth. That is to say, to 4 times the square of the length add the square of the breadth, and divide the sum by 12; the radius of gyration is equal to the square root of the quotient.

## Centre of Oscillation.

The centre of oscillation of a body vibrating about a fixed axis or point of suspension, by the action of gravity, is the resultant centre of the force or work alternately accumulated and neutralised by gravitation in the oscillating mass during each vibration. It is so situated that if all parts of the body were concentrated there, the quantity of work alternately accumulated and neutralised would continue unaltered, and the body would continue to vibrate in the same time. The centre of oscillation is in the straight line which joins the centre of gravity to the axis of oscillation. The particles of the body have velocities varying with the distance of the particles from the axis, and if the moment of inertia of the body, the method of finding which has already been explained, be divided by the weight of the body, and by the distance of the centre of gravity from the centre of suspension, the quotient will be the length of the resultant radius of oscillation, at the end of which is the centre of oscillation. Putting I and $w$, as before, for the moment of inertia and the weight of the body respectively, $r/o$ for the radius of oscillation, and $r/g$ for the radius of the centre of gravity, then,—

$$r/o = \frac{I}{w \times r/g} \quad . \quad . \quad . \quad . \quad . \quad (19)$$

$$\text{and } r/o \times r/g = \frac{I}{w} \quad . \quad . \quad . \quad . \quad . \quad (20)$$

But $\frac{I}{w}$ is equal to $\sqrt{\frac{I}{w}} \times \sqrt{\frac{I}{w}}$, or $(r \times r)$, the square of the radius of gyration, consequently,

$$r/g : r :: r : r/o \quad . \quad . \quad . \quad . \quad (21)$$

That is to say, the radius of oscillation is a third proportional to the radius of the centre of gravity and the radius of gyration, and finally,

$$\text{Radius of oscillation} = \frac{\text{radius}^2 \text{ of gyration}}{\text{radius of centre of gravity}} \quad . \quad (22)$$

In a straight line, or a uniform thin bar or cylinder, suspended by one end, oscillating about it as an axis, the centre of oscillation is at $\frac{2}{3}$rds of the length of the rod from the axis.

In a straight line or thin bar of uniform thickness, but in which the density of its particles increase as the distance from the axis, the centre of oscillation is at $\frac{3}{4}$ths of the length of the rod from the axis.

In a straight line or uniform thin bar, suspended at a point one-third of the length below the upper end of the bar, the centre of oscillation is at $\frac{2}{3}$rds of the length below the axis, or it is coincident with the lower end of the bar. That is to say, whether a thin bar be suspended at one end or at a point one-third of its length below the upper end, the vibrations will be performed in the same time. The limit of transition of the axis is at half the length of the bar, round which point it does not oscillate at all, the centre of oscillation being indefinitely removed.

The lengths of the radius of oscillation of a few regular plane figures or thin plates, suspended by the vertex or uppermost point, are as follows :—

1st. When the vibrations are flatwise, or perpendicular to the plane of the figure :

In an isosceles triangle the radius of oscillation is equal to $\frac{3}{4}$ths of the height of the triangle.

In a circle, $\frac{5}{8}$ths of the diameter.

In a parabola, $\frac{5}{7}$ths of the height.

2nd. When the vibrations are edgewise, or in the plane of the figure :

In a circle the radius of oscillation is $\frac{3}{4}$ths of the diameter.

In a rectangle suspended by one angle, $\frac{2}{3}$rds of the diagonal.

In a parabola, suspended by the vertex, $\frac{5}{7}$ths of the height, plus $\frac{1}{3}$rd of the parameter.

In a parabola, suspended by the middle of the base, $\frac{4}{7}$ths of the height plus $\frac{1}{2}$ the parameter.

In a sector of a circle suspended by the centre, $\frac{3}{4}$ths of the geometrical radius multiplied by the length of the arc, and divided by the length of the chord.

The length of the radius of oscillation of a cone is $\frac{4}{5}$ths of the height, plus the quotient obtained by dividing the square of the radius of the base by five times the height. If a right-angled cone be suspended at its vertex, the centre of oscillation will coincide with the centre of its base, and the cone will vibrate in the same time as a simple pendulum of which the length is equal to the height of the cone.

That of a sphere suspended by a cord is $\frac{2}{5}$ths of the square of the geometrical radius, divided by the length of the cord measured to the centre of the sphere, plus the length of the chord so taken. For example, in a sphere 8 inches in diameter, suspended by a cord or a light rod 20 inches long, as measured between the centre of suspension and the centre of the sphere, the radius of oscillation is equal to,—

$$\frac{2 \times 4^2}{5 \times 20} + 20 = \cdot 32 + 20 = 20 \cdot 32 \text{ inches,}$$

or ·32 inch below the centre of the sphere.

If the point of suspension be at the surface of the sphere, or at the extremity of a geometrical radius, the radius of oscillation is equal to $\frac{7}{5}$ths of the radius, or $\frac{7}{10}$ths of the diameter.

### Centre of Percussion.

The centre of percussion of a body oscillating or vibrating about a fixed axis, is identical with the centre of oscillation, which is the point at which, if a blow is struck, the percussive action is the same as if the whole mass of the body were concentrated at the point.

### The Pendulum.

A "simple pendulum" is defined as a heavy particle attached to one end of a cord or a rod without weight, and caused to vibrate on the centre of suspension. The time of vibration of an ordinary pendulum depends on the angle or arc of vibration; but for arcs of vibration not exceeding 4 or 5 degrees, the time of vibration is sensibly the same for any length of arc within that limit. This uniformity of time of vibration is called isochronism.

The length or radius of oscillation of the pendulum vibrating seconds, at the level of the sea, in the latitude of London, is 39·1393 inches. The lengths for other places are given

in page 430. A few of these are here reproduced in inches:—

| | Inches. |
|---|---|
| Equator | 39·0168 |
| Latitude 45° | 39·1164 |
| Paris | 39·1308 |
| London | 39·1393 |
| Berlin | 39·1428 |
| Edinburgh | 39·1548 |
| Aberdeen | 39·1584 |
| Pole | 39·2184 |

The times of vibration of pendulums within the limits already given, are as the square roots of the lengths of the pendulums. The lengths of pendulums are to each other as the squares of the times of one vibration; or inversely as the squares of the numbers of vibrations in a given time.

The square root of the length of the pendulum vibrating seconds at London, or $\sqrt{39 \cdot 1393} = 6 \cdot 2561$; and the time of a vibration of any pendulum is equal to the square root of the given length in inches divided by 6·2561, or,

$$t = \frac{\sqrt{l}}{6 \cdot 2561} \qquad . \quad . \quad . \qquad (23)$$

$t$ = the time of one vibration in seconds.
$l$ = the length of the pendulum in inches.
$n$ = the number of vibrations per second, or per minute.

To find the number of vibrations per second of a pendulum of a given length, divide 6·2561 by the square root of the length in inches.

The number of vibrations per minute is found by dividing 375·366 by the square root of the length in inches; or,

$$\text{(per second) } n = \frac{6 \cdot 2561}{\sqrt{l}} \qquad . \quad . \quad . \quad . \qquad (24)$$

$$\text{(per minute) } n = \frac{375 \cdot 366}{\sqrt{l}} \qquad . \quad . \quad . \quad . \qquad (25)$$

The length of a pendulum in inches to make one vibration in a given time, is found by multiplying the square of the time in seconds by 39·1393; or,

$$l = t^2 \times 39 \cdot 1393 \qquad . \quad . \quad . \qquad (26)$$

The length of a pendulum in inches to make a given number of vibrations per second is equal to the quotient of 39·1393 divided by the square of the number of vibrations.

Or, when the number of vibrations per minute is given, divide 140,900 by the square of the number ; or,

$$l = \frac{39{\cdot}1393}{n^2 \text{ (per second)}} \quad . \quad . \quad . \quad (27)$$

$$l = \frac{140{,}900}{n^2 \text{ (per minute)}} \quad . \quad . \quad . \quad (28)$$

The time of vibration of a pendulum may be varied by the addition of a weight, which, when applied at a point above the centre of suspension, counteracts the lower weight, and lengthens the period of vibration. By varying the height of the upper weight the time is varied.

To find the weight of the upper bob of a compound pendulum, necessary to vibrate seconds, when the weight of the lower bob is given, with the distances of the weights from the point of suspension, the following is the formula :—

$$w = W\frac{(39{\cdot}1393 + D) - D^2}{(39{\cdot}139 + d) + d^2} \quad . \quad . \quad . \quad (29)$$

W = the weight of the lower bob.

$w$ = the weight of the upper bob.

D = the distance of the lower bob from the centre, in inches.

$d$ = the distance of the upper bob from the centre, in inches.

Thus, by means of a second bob, short pendulums may be constructed to vibrate as slowly as longer pendulums.

## Gravity and Fall of Bodies.

The motion and velocity of a body freely falling vertically, is uniformly accelerated, equal additions of velocity being acquired in equal times. There are three elements concerned in the fall of a body, *height* fallen through, *velocity* acquired, and *time* of fall.

The force of gravity is expressed by the velocity in feet per second, communicated by gravity to a body falling freely in a second, namely, 32·189, or, say, 32·2 feet per second, as at London ; and it is represented by the symbol $g$.

The force of gravity varies slightly according to the latitude, as is shown by the following table, in which the length of the pendulum beating seconds is added :—

TABLE 227.—GRAVITY; LENGTH OF SECONDS PENDULUM.

| Locality. | Latitude. | | Force of Gravity at the Level of the Sea: Value of $g$. | Length of Pendulum beating Seconds, at the Level of the Sea. |
|---|---|---|---|---|
| | Degs. | Secs. | Feet per Second. | Feet. |
| Equator | 0 | 0 | 32·091 | 3·2514 |
| Latitude 45° | 45 | 0 | 32·173 | 3·2597 |
| Paris | 48 | 50 | 32·183 | 3·2609 |
| Greenwich (London) | 51 | 29 | 32·191 | 3·2616 |
| Berlin | 52 | 30 | 32·194 | 3·2619 |
| Dublin | 53 | 21 | 32·196 | 3·2621 |
| Manchester | 53 | 29 | 32·196 | 3·2622 |
| Edinburgh | 55 | 57 | 32·203 | 3·2629 |
| Aberdeen | 57 | 9 | 32·206 | 3·2632 |
| Pole | 90 | 0 | 32·255 | 3·2682 |

The relations of time, height of fall, and velocity, are expressible as follows:—

Total time as . . . 1, 2, 3, 4, &c.
Velocity acquired as . . 1, 2, 3, 4, &c.
Height of Fall as . . 1, 4, 9, 16, &c.
Or as . . . . 1, $2^2$, $3^2$, $4^2$, &c.

Whilst the velocity is increased simply with the time, the height fallen increases as the square of the time, and as the square of the velocity. These relations are formulated in the following rules, in which,—

$t$ = time, in seconds.
$h$ = height fallen, in feet.
$v$ = velocity acquired, in feet per second.

RULE 1.—To find the *velocity acquired*, given the height of fall, multiply the height by 64·4, and take the square root of the quotient.

Or, multiply the square root of the height by 8. The exact value of the coefficient is 8·025, but 8 is usually taken for ordinary calculations.

These rules are formulated thus:—

$$v = \sqrt{64{\cdot}4\, h} \quad . \quad . \quad . \quad . \quad . \quad (30)$$

$$\text{Or } v = 8\sqrt{h} \quad . \quad . \quad . \quad . \quad . \quad . \quad (31)$$

RULE 2.—To find the *velocity acquired*, given the time of fall. Multiply the time in seconds by 32·2. Or,

$$v = 32{\cdot}2\, t \quad . \quad . \quad . \quad . \quad . \quad (32)$$

RULE 3.—To find the *height of fall*, given the velocity acquired. Square the velocity, and divide by 64·4. Or,

$$h = \frac{v^2}{64 \cdot 4} \quad . \quad . \quad . \quad . \quad . \quad (33)$$

RULE 4.—To find the *height of fall*, given the time. Multiply the square of the time by 16·1. Or,

$$h = 16 \cdot 1\, t^2 \quad . \quad . \quad . \quad . \quad . \quad (34)$$

RULE 5.—To find the *height of fall*, given the velocity and the time. Multiply the velocity by the time, and divide by 2. Or,

$$h = \frac{v\,t}{2} \quad . \quad . \quad . \quad . \quad . \quad . \quad (35)$$

RULE 6.—To find the *time of fall*, given the velocity acquired. Divide the velocity by 32·2. Or,

$$t = \frac{v}{32 \cdot 2} \quad . \quad . \quad . \quad . \quad . \quad (36)$$

RULE 7.—To find the *time of fall*, given the height. Divide the height by 16·1; and find the square root of the quotient.

Or, multiply the square root of the height by ·2492.

Or, take one-fourth of the square root of the height, to find the time very nearly (within one-tenth of one per cent. of error by excess). Or,

$$t = \sqrt{\frac{h}{16 \cdot 1}} \quad . \quad . \quad . \quad . \quad (37)$$

$$\text{Or, } t = \cdot 2492 \sqrt{h} \quad . \quad . \quad . \quad . \quad (38)$$

$$\text{Or, } t = \tfrac{1}{4} \sqrt{h} \text{ (very nearly)} \quad . \quad (39)$$

The above rules, drawn for falling bodies, are available also for the case of bodies projected freely upwards in opposition to gravity and uniformly retarded by it. The symbol $v$ is expressive of the initial velocity with which the ascending body is propelled; $h$ is the height to which it rises; $t$ is the time of ascent.

The formula (33) for the height due to the velocity may be adapted for finding the head due to a velocity $v_1$ expressed in miles per hour. A speed of 1 mile per hour is equivalent to 1·46 feet per second, and the formula becomes by substitution, $h = \frac{1 \cdot 46 v_1^2}{64 \cdot 4}$.

By reduction, the following rule is obtained :—

RULE 7.—To find the *height* due to the velocity or speed in miles per hour. Divide the square of the speed by 29·94. Or

$$h = \frac{v_1^2}{29 \cdot 94} \quad . \quad . \quad . \quad . \quad . \quad (40)$$

The following table contains the times of fall, and the final velocities due to given heights of fall; Table 229 gives, conversely, the heights of fall due to given velocities; Table 230 gives the heights of fall and the final velocities due to given times of fall; Table 231 gives the heights of fall due to given speeds in miles per hour.

TABLE 228.—FALLING BODIES:—HEIGHT OF FALL, AND CORRESPONDING TIME OF FALL, AND FINAL VELOCITY.

$t = \cdot 2492\sqrt{h}$. $v = 8\cdot 025\sqrt{h}$.

| Height of Fall. | Time of Fall. | Velocity acquired in Feet per Second. | Height of Fall. | Time of Fall. | Velocity acquired in Feet per Second. | Height of Fall. | Time of Fall. | Velocity acquired in Feet per Second. |
|---|---|---|---|---|---|---|---|---|
| Feet. | Secs. | Feet per Sec. | Feet. | Secs. | Feet per Sec. | Feet. | Secs. | Feet per Sec. |
| ·01 | ·025 | ·803 | 1·4 | ·295 | 9·50 | 4·5 | ·529 | 17·03 |
| ·02 | ·035 | 1·14 | 1·5 | ·305 | 9·83 | 4·6 | ·534 | 17·21 |
| ·03 | ·043 | 1·39 | 1·6 | ·315 | 10·15 | 4·7 | ·540 | 17·40 |
| ·04 | ·050 | 1·61 | 1·7 | ·325 | 10·46 | 4·8 | ·546 | 17·58 |
| ·05 | ·056 | 1·80 | 1·8 | ·334 | 10·77 | 4·9 | ·552 | 17·78 |
| ·06 | ·061 | 1·97 | 1·9 | ·344 | 11·06 | 5·0 | ·557 | 17·99 |
| ·07 | ·066 | 2·12 | 2·0 | ·353 | 11·35 | 5·25 | ·571 | 18·41 |
| ·08 | ·071 | 2·27 | 2·1 | ·361 | 11·63 | 5·5 | ·585 | 18·82 |
| ·09 | ·075 | 2·41 | 2·2 | ·370 | 11·90 | 5·75 | ·598 | 19·24 |
| ·1 | ·079 | 2·54 | 2·3 | ·378 | 12·17 | 6·0 | ·611 | 19·66 |
| ·15 | ·097 | 3·11 | 2·4 | ·386 | 12·43 | 6·25 | ·623 | 20·07 |
| ·2 | ·112 | 3·59 | 2·5 | ·394 | 12·69 | 6·5 | ·635 | 20·46 |
| ·25 | ·125 | 4·01 | 2·6 | ·402 | 12·94 | 6·75 | ·647 | 20·85 |
| ·3 | ·137 | 4·40 | 2·7 | ·410 | 13·19 | 7·0 | ·659 | 21·23 |
| ·35 | ·147 | 4·75 | 2·8 | ·417 | 13·43 | 7·25 | ·672 | 21·61 |
| ·4 | ·158 | 5·07 | 2·9 | ·424 | 13·67 | 7·5 | ·683 | 21·97 |
| ·45 | ·167 | 5·38 | 3·0 | ·432 | 13·90 | 7·75 | ·694 | 22·33 |
| ·5 | ·176 | 5·68 | 3·1 | ·439 | 14·13 | 8·0 | ·705 | 22·69 |
| ·55 | ·185 | 5·95 | 3·2 | ·446 | 14·36 | 8·25 | ·716 | 23·05 |
| ·6 | ·193 | 6·22 | 3·3 | ·453 | 14·58 | 8·5 | ·727 | 23·40 |
| ·65 | ·201 | 6·47 | 3·4 | ·459 | 14·80 | 8·75 | ·737 | 23·74 |
| ·7 | ·209 | 6·71 | 3·5 | ·466 | 15·01 | 9·0 | ·746 | 24·07 |
| ·75 | ·216 | 6·95 | 3·6 | ·473 | 15·22 | 9·25 | ·757 | 24·40 |
| ·8 | ·223 | 7·18 | 3·7 | ·480 | 15·43 | 9·5 | ·768 | 24·73 |
| ·85 | ·230 | 7·40 | 3·8 | ·486 | 15·64 | 9·75 | ·778 | 25·06 |
| ·9 | ·236 | 7·61 | 3·9 | ·492 | 15·85 | 10 | ·788 | 25·38 |
| ·95 | ·243 | 7·82 | 4·0 | ·498 | 16·05 | 10·5 | ·808 | 26·01 |
| 1·0 | ·249 | 8·03 | 4·1 | ·505 | 16·25 | 11 | ·827 | 26·62 |
| [illegible] | ·261 | 8·42 | 4·2 | ·511 | 16·45 | 11·5 | ·845 | 27·22 |
| [illegible] | ·273 | 8·79 | 4·3 | ·517 | 16·64 | 12 | ·863 | 27·80 |
| [illegible] | [illegible]4 | 9·15 | 4·4 | ·523 | 16·84 | 12·5 | ·881 | 28·37 |

TABLE 228.—FALL, TIME, AND VELOCITY (*continued*).

| Height of Fall. | Time of Fall. | Velocity acquired in Feet per Second. | Height of Fall. | Time of Fall. | Velocity acquired in Feet per Second. | Height of Fall. | Time of Fall. | Velocity acquired in Feet per Second. |
|---|---|---|---|---|---|---|---|---|
| Feet. | Secs. | Feet per Sec. | Feet. | Secs. | Feet per Sec. | Feet. | Secs. | Feet per Sec. |
| 13 | ·899 | 28·93 | 43 | 1·634 | 52·62 | 160 | 3·152 | 101·5 |
| 13·5 | ·916 | 29·49 | 44 | 1·653 | 53·23 | 170 | 3·250 | 104·6 |
| 14 | ·933 | 30·03 | 45 | 1·672 | 53·83 | 180 | 3·344 | 107·9 |
| 14·5 | ·949 | 30·56 | 46 | 1·690 | 54·43 | 190 | 3·435 | 110·6 |
| 15 | ·965 | 31·08 | 47 | 1·709 | 55·02 | 200 | 3·525 | 113·5 |
| 15·5 | ·981 | 31·59 | 48 | 1·727 | 55·60 | 225 | 3·738 | 120·4 |
| 16 | ·997 | 32·00 | 49 | 1·745 | 56·17 | 250 | 3·941 | 126·9 |
| 16·1 | 1·000 | 32·20 | 50 | 1·762 | 56·74 | 275 | 4·133 | 133·1 |
| 16·5 | 1·013 | 32·60 | 52 | 1·797 | 57·87 | 300 | 4·317 | 139·0 |
| 17 | 1·028 | 33·09 | 54 | 1·831 | 58·97 | 325 | 4·493 | 144·7 |
| 17·5 | 1·033 | 33·57 | 56 | 1·865 | 60·05 | 350 | 4·663 | 150·1 |
| 18 | 1·057 | 34·05 | 58 | 1·898 | 61·12 | 375 | 4·826 | 155·4 |
| 18·5 | 1·072 | 34·52 | 60 | 1·930 | 62·16 | 400 | 4·984 | 160·5 |
| 19 | 1·086 | 34·98 | 62 | 1·962 | 63·19 | 425 | 5·138 | 165·4 |
| 19·5 | 1·101 | 35·44 | 64 | 1·994 | 64·20 | 450 | 5·287 | 170·2 |
| 20 | 1·115 | 35·89 | 66 | 2·025 | 65·20 | 475 | 5·432 | 174·9 |
| 21 | 1·141 | 36·77 | 68 | 2·055 | 66·18 | 500 | 5·573 | 179·9 |
| 22 | 1·167 | 37·64 | 70 | 2·085 | 67·14 | 550 | 5·845 | 188·2 |
| 23 | 1·194 | 38·49 | 72 | 2·115 | 68·09 | 600 | 6·105 | 196·6 |
| 24 | 1·221 | 39·31 | 74 | 2·144 | 69·03 | 650 | 6·354 | 204·6 |
| 25 | 1·246 | 40·12 | 76 | 2·173 | 69·96 | 700 | 6·594 | 212·3 |
| 26 | 1·271 | 40·92 | 78 | 2·201 | 70·87 | 750 | 6·825 | 219·8 |
| 27 | 1·295 | 41·70 | 80 | 2·229 | 71·78 | 800 | 7·049 | 226·9 |
| 28 | 1·319 | 42·47 | 82 | 2·257 | 72·67 | 850 | 7·266 | 234·0 |
| 29 | 1·342 | 43·22 | 84 | 2·284 | 73·55 | 900 | 7·477 | 240·7 |
| 30 | 1·365 | 43·95 | 86 | 2·311 | 74·42 | 950 | 7·681 | 247·3 |
| 31 | 1·388 | 44·68 | 88 | 2·338 | 75·28 | 1000 | 7·881 | 253·8 |
| 32 | 1·410 | 45·39 | 90 | 2·364 | 76·13 | 1500 | 9·652 | 310·8 |
| 33 | 1·432 | 46·10 | 92 | 2·390 | 76·97 | 2000 | 11·15 | 358·9 |
| 34 | 1·453 | 46·79 | 94 | 2·416 | 77·81 | 2500 | 12·46 | 401·2 |
| 35 | 1·474 | 47·47 | 96 | 2·442 | 78·63 | 3000 | 13·65 | 439·5 |
| 36 | 1·495 | 48·15 | 98 | 2·467 | 79·45 | 3500 | 14·74 | 474·7 |
| 37 | 1·516 | 48·81 | 100 | 2·492 | 80·25 | 4000 | 15·76 | 507·5 |
| 38 | 1·536 | 49·47 | 110 | 2·614 | 84·17 | 4500 | 16·72 | 538·3 |
| 39 | 1·556 | 50·11 | 120 | 2·730 | 87·91 | 5000 | 17·62 | 567·4 |
| 40 | 1·576 | 50·75 | 130 | 2·842 | 91·50 | 7500 | 21·58 | 695·0 |
| 41 | 1·596 | 51·38 | 140 | 2·949 | 94·95 | 10000 | 24·92 | 802·5 |
| 42 | 1·615 | 52·01 | 150 | 3·052 | 98·28 | | | |

## TABLE 229.—FALLING BODIES:—FINAL VELOCITY AND CORRESPONDING HEIGHT OF FALL.

$$h = \frac{v^2}{64 \cdot 4}$$

| Velocity in Feet per Second. | Height of Fall. | Velocity in Feet per Second. | Height of Fall. | Velocity in Feet per Second. | Height of Fall. | Velocity in Feet per Second. | Height of Fall. |
|---|---|---|---|---|---|---|---|
| Feet per Sec. | Feet. | Feet per Sec. | Feet. | Feet per Sec. | Feet. | Feet per Sec. | Feet. |
| ·25 | ·0010 | 24 | 8·94 | 56 | 48·7 | 87 | 117·5 |
| ·50 | ·0039 | 25 | 9·71 | 57 | 50·4 | 88 | 120·2 |
| ·75 | ·0087 | 26 | 10·5 | 58 | 52·2 | 89 | 123·0 |
| 1·00 | ·016 | 27 | 11·3 | 59 | 54·1 | 90 | 125·8 |
| 1·25 | ·024 | 28 | 11·2 | 60 | 55·9 | 91 | 128·6 |
| 1·50 | ·035 | 29 | 13·1 | 61 | 57·8 | 92 | 131·4 |
| 1·75 | ·048 | 30 | 14·0 | 62 | 59·7 | 93 | 134·3 |
| 2 | ·062 | 31 | 14·9 | 63 | 61·6 | 94 | 137·2 |
| 2·5 | ·097 | 32 | 15·9 | 64 | 63·6 | 95 | 140·1 |
| 3 | ·140 | 33 | 16·9 | 65 | 65·6 | 96 | 143·1 |
| 3·5 | ·190 | 34 | 17·9 | 66 | 67·6 | 97 | 146·1 |
| 4 | ·248 | 35 | 19·0 | 67 | 69·7 | 98 | 149·1 |
| 4·5 | ·314 | 36 | 20·1 | 68 | 71·8 | 99 | 152·2 |
| 5 | ·388 | 37 | 21·3 | 69 | 73·9 | 100 | 155·3 |
| 6 | ·559 | 38 | 22·4 | 70 | 76·1 | 105 | 171·2 |
| 7 | ·761 | 39 | 23·6 | 71 | 78·3 | 110 | 187·9 |
| 8 | ·994 | 40 | 24·9 | 72 | 80·5 | 115 | 205·4 |
| 9 | 1·26 | 41 | 26·1 | 73 | 82·7 | 120 | 223·6 |
| 10 | 1·55 | 42 | 27·4 | 74 | 85·0 | 130 | 262·4 |
| 11 | 1·88 | 43 | 28·7 | 75 | 87·4 | 140 | 304·3 |
| 12 | 2·24 | 44 | 30·1 | 76 | 89·7 | 150 | 349·4 |
| 13 | 2·62 | 45 | 31·4 | 77 | 92·1 | 175 | 475·5 |
| 14 | 3·04 | 46 | 32·9 | 78 | 94·5 | 200 | 621 |
| 15 | 3·49 | 47 | 34·3 | 79 | 96·9 | 300 | 1397 |
| 16 | 3·98 | 48 | 35·8 | 80 | 99·4 | 400 | 2484 |
| 17 | 4·49 | 49 | 37·3 | 81 | 101·9 | 500 | 3882 |
| 18 | 5·03 | 50 | 38·8 | 82 | 104·4 | 600 | 5590 |
| 19 | 5·61 | 51 | 40·4 | 83 | 107·0 | 700 | 7609 |
| 20 | 6·21 | 52 | 42·0 | 84 | 109·5 | 800 | 9938 |
| 21 | 6·85 | 53 | 43·6 | 85 | 112·2 | 900 | 12578 |
| 22 | 7·52 | 54 | 45·3 | 86 | 114·8 | 1000 | 15528 |
| 23 | 8·21 | 55 | 47·0 | | | | |

TABLE 230.—FALLING BODIES:—TIME OF FALL AND CORRESPONDING HEIGHT OF FALL AND FINAL VELOCITY.

$$h = 16{\cdot}1\,t^2. \qquad v = 32{\cdot}2\,t.$$

| Time of Fall. | Height of Fall. | Velocity acquired in Feet per Second. | Time of Fall. | Height of Fall. | Velocity acquired in Feet per Second. | Time of Fall. | Height of Fall. | Velocity acquired in Feet per Second. |
|---|---|---|---|---|---|---|---|---|
| Secs. | Feet. | Feet per Sec. | Secs. | Feet. | Feet per Sec. | Secs. | Feet. | Feet per Sec. |
| 1 | 16·1 | 32·2 | 12 | 2318 | 386·4 | 23 | 8517 | 740·6 |
| 2 | 64·4 | 64·4 | 13 | 2721 | 418·6 | 24 | 9273 | 772·8 |
| 3 | 144·9 | 96·6 | 14 | 3156 | 450·8 | 25 | 10062 | 805·0 |
| 4 | 257·6 | 128·8 | 15 | 3623 | 483·0 | 26 | 10884 | 837·2 |
| 5 | 402·5 | 161·0 | 16 | 4122 | 515·2 | 27 | 11737 | 869·4 |
| 6 | 579·6 | 193·2 | 17 | 4653 | 547·4 | 28 | 12622 | 901·6 |
| 7 | 788·9 | 225·4 | 18 | 5217 | 579·6 | 29 | 13540 | 933·8 |
| 8 | 1030 | 257·6 | 19 | 5812 | 611·8 | 30 | 14490 | 966·0 |
| 9 | 1304 | 289·8 | 20 | 6440 | 644·0 | 31 | 15473 | 998·2 |
| 10 | 1610 | 322·0 | 21 | 7100 | 676·2 | 32 | 16487 | 1030 |
| 11 | 1948 | 354·2 | 22 | 7792 | 708·4 | | | |

TABLE 231.—FALLING BODIES:—SPEED IN MILES PER HOUR AND HEIGHT DUE TO THE SPEED.

$$h = \frac{\text{speed}^2}{29{\cdot}938}.$$

| Speed in Miles per Hour. | Velocity in Feet per Second. | Height due to the Speed. | Speed in Miles per Hour. | Velocity in Feet per Second. | Height due to the Speed. |
|---|---|---|---|---|---|
| Miles. | Feet. | Feet. | Miles. | Feet. | Feet. |
| 1 | 1·46 | ·033 | 50 | 73·33 | 83·51 |
| 5 | 7·33 | ·835 | 60 | 87·99 | 120·2 |
| 10 | 14·66 | 3·34 | 70 | 102·66 | 163·7 |
| 20 | 29·33 | 13·36 | 80 | 117·33 | 213·8 |
| 30 | 43·99 | 30·07 | 90 | 131·99 | 270·6 |
| 40 | 58·66 | 53·44 | 100 | 146·66 | 334·0 |

**Accelerating and Retarding Forces in General.**

The formulæ for falling bodies acted on by gravity, may be adapted for the action of uniformly accelerating and retarding forces generally. Let $t$ be the time in seconds

during which an accelerating force is applied to the body, supposing that the body is started from a state of rest; $v$ the final velocity acquired; $s$ the space in feet traversed by the body during the time—the equivalent of the height in the rules for gravity; $f$ the accelerating force in pounds; $w$ the weight of the body in pounds. The velocity acquired is directly as the accelerating force, and inversely as the weight of the body.

## Rules for Accelerated Motion.

RULE 1.—To find *the final velocity*, given the weight, the force, and the space. Multiply the force by the space, and divide by the weight; find the square root of the quotient, and multiply by 8. Or,

$$v = 8\sqrt{\frac{fs}{w}} \quad . \quad . \quad . \quad (41)$$

RULE 2.—To find *the final velocity*, given the weight, the force, and the time. Multiply the force by the time, and by 32·2, and divide by the weight. Or,

$$v = \frac{32{\cdot}2ft}{w} \quad . \quad . \quad . \quad . \quad (42)$$

RULE 3.—To find *the force*, given the weight, the final velocity, and the space. Multiply the weight by the square of the final velocity, and divide by the space, and by 64·4. Or,

$$f = \frac{wv^2}{64{\cdot}4s} \quad . \quad . \quad . \quad . \quad . \quad (43)$$

RULE 4.—To find *the force*, given the weight, the final velocity, and the time. Multiply the weight by the velocity, and divide by the time, and by 32·2. Or,

$$f = \frac{wv}{32{\cdot}2t} \quad . \quad . \quad . \quad . \quad . \quad (44)$$

RULE 5.—To find *the weight*, given the force, the velocity, and the space. Multiply the force by the space, and by 64·4, and divide by the square of the velocity. Or,

$$w = \frac{64{\cdot}4fs}{v^2} \quad . \quad . \quad . \quad . \quad . \quad (45)$$

RULE 6.—To find *the space*, given the weight, the final velocity, and the force. Multiply the weight by the square of the velocity, and divide by the force, and by 64·4. Or,

$$s = \frac{wv^2}{64{\cdot}4f} \quad . \quad . \quad . \quad . \quad . \quad (46)$$

RULE 7.—To find *the space*, given the weight, the force, and the time. Multiply the force by the square of the time, and by 16·1, and divide by the weight. Or,

$$s=\frac{16{\cdot}1ft^2}{w} \quad . \quad . \quad . \quad . \quad . \quad (47)$$

RULE 8.—To find *the space*, given the velocity and the time. Multiply the velocity by the time, and divide by 2.

$$s=\frac{vt}{2} \quad . \quad . \quad . \quad . \quad . \quad . \quad (48)$$

RULE 9.—To find *the time*, given the weight, the force, and the final velocity. Multiply the weight by the velocity, and divide by the force, and by 32·2. Or,

$$t=\frac{wv}{32{\cdot}2f} \quad . \quad . \quad . \quad (49)$$

RULE 10.—To find *the time*, given the weight, the force, and the space. Multiply the weight by the space, and divide by the force; find the square root of the quotient, and divide by 4. Or,

$$t=\tfrac{1}{4}\sqrt{\frac{ws}{f}} \quad . \quad . \quad . \quad . \quad . \quad (50)$$

The foregoing formulæ are available for calculating questions of retarded motion; $v$ being the initial velocity, $f$ the retarding force, $w$ the weight of the body, $s$ the space in which the motion is reduced to nothing, and $t$ the time of retardation.

RULE 11.—To find the *accelerating or retarding force* in a body which is in motion at the beginning and end of the space traversed, when the space is given, and also the velocities at the beginning and the end of the space. Divide the difference of the squares of the velocities by the space and by 64·4, and multiply by the weight. The product is the accelerating or retarding force, according as the less or the greater velocity is the initial velocity. Or,

$$f=w\left(\frac{v^2-v_1{}^2}{64{\cdot}4s}\right) \quad . \quad . \quad . \quad . \quad (51)$$

*Note.*—When the weight and the force are in simple relation to each other, expressible by a simple fraction, the terms of the fraction may be substituted for $w$ and $f$ in the formulæ (41), (42), (46), (47), (49), (50), and calculation simplified.

### Descent of Bodies on Inclined Planes.

The descent of a body on an inclined plane by the gravitation of the body, is a case of an accelerating force less than

that of gravity on a vertically falling body; to be solved by the aid of the general formulas for accelerating forces. The accelerating force of gravitation on an inclined plane is to the direct force of gravity in the ratio of the height of the plane to the length of the plane; and it is therefore inversely proportional to the length of the plane, when the height is the same. The accelerating force $v$ is determined by multiplying the weight of the descending body by the height of the plane, and dividing the product by the length of the plane. For instance, a body weighing 100 lbs., on an inclined plane 1000 feet long and 20 feet high, is controlled by an accelerating force of $(100 \times \frac{20}{1000} = 100 \times \frac{1}{50} =)$ 2 pounds. But, inasmuch as the accelerating force acts through a space, or length of incline, proportionally longer as the force is less, the time of descent is also proportionally longer, and the final velocity acquired at the foot of the incline is equal to that due to the vertical height for a falling body. These relations are deduced without allowance for external resistances.

To adjust formula (50) for finding the time of free descent of an inclined plane:—$w$ and $f$ being in proportion to $l$, the length of the plane, and $h$ the height of it, these may be substituted for $w$ and $f$ in the formula, and $t = \frac{1}{4}\sqrt{\frac{ws}{f}}$ becomes $t = \frac{1}{4}\sqrt{\frac{ls}{h}}$; and, as $s = l$, $t = \frac{1}{4}\sqrt{\frac{l^2}{h}}$; or, finally,

$$t = \frac{l}{4\sqrt{h}} \quad . \quad . \quad . \quad . \quad . \quad (52)$$

RULE 1.—To find the *time* of descent, given the length and the height of the inclined plane. Divide the length of the plane by 4 times the square root of the height of the plane.

## Central Forces.

When a body revolves about an axis or centre, it is subject to centrifugal force, by which it is urged to fly from the centre; and to centripetal force, the reactive force by which the centrifugal force is balanced, and by which the body is constrained to move in a circular path. These are known as central forces.

Central force varies as the square of the speed of revolution, whether in terms of the linear or circumferential velocity, or of the angular speed in revolutions per unit of time.

It varies as the radius of the circle of revolution.

It varies as the mass or weight of the revolving body.

Let :—

$w$ = the weight of the revolving body, in pounds.

$\frac{w}{g} = \frac{w}{32 \cdot 2}$ = the mass of the body ; $g$ representing gravity.

$v$ = the linear or circumferential velocity in feet per second.

$v_1$ = the angular velocity, or revolutions per second.

$f$ = the centrifugal force in pounds.

$r$ = the radius of gyration of the revolving body, in feet.

*Rules for Centrifugal Force in terms of Circumferential Velocity.*

RULE 1.—To find the *centrifugal force*, given the weight, the linear velocity, and the radius of gyration. Multiply the weight by the square of the linear velocity, and divide by 32·2 times the radius of gyration. Or,

$$f = \frac{wv^2}{32 \cdot 2r} \quad . \quad . \quad . \quad . \quad . \quad (53)$$

RULE 2.—To find the *linear velocity*, when the weight, the centrifugal force, and the radius of gyration are given. Multiply the centrifugal force by the radius of gyration, and by 32·2, and divide by the weight ; take the square root of the quotient. Or,

$$v = \sqrt{\frac{32 \cdot 2fr}{w}} \quad . \quad . \quad . \quad . \quad . \quad (54)$$

RULE 3.—To find the *weight*, when the centrifugal force, the linear velocity, and the radius of gyration are given. Multiply the centrifugal force by the radius of gyration, and by 32·2, and divide by the square of the velocity. Or,

$$w = \frac{32 \cdot 2fr}{v^2} \quad . \quad . \quad . \quad . \quad . \quad (55)$$

RULE 4.—To find the *radius of gyration*, when the weight, the linear velocity, and the centrifugal force are given. Multiply the weight by the square of the velocity, and divide by the centrifugal force, and by 32·2. Or,

$$r = \frac{wv^2}{32 \cdot 2f} \quad . \quad . \quad . \quad . \quad . \quad (56)$$

*Rules for Centrifugal Force in terms of Angular Velocity.*

The linear velocity $v$ is equal to the angular velocity, $v_1$, multiplied by the radius of gyration and by 6·2832 (twice 3·1416). Or,

$$v = 6 \cdot 2832 v_1 r \quad . \quad . \quad . \quad . \quad . \quad (57)$$

By substitution, in equation (53), and reduction, formula (58) is produced.

RULE 5.—To find *the centrifugal force*, when the weight, the angular velocity, and the radius of gyration are given. Multiply the weight by the square of the angular velocity and by the radius of gyration, and by 1·226. Or,

$$f = 1{\cdot}226 w v_1^2 r \quad . \quad . \quad . \quad . \quad . \quad (58)$$

RULE 6.—To find *the angular velocity*, when the weight, the centrifugal force, and the radius of gyration are given. Multiply the weight by the radius of gyration, and by 1·226; divide the centrifugal force by the product so produced; and take the square root of the quotient. Or,

$$v_1 = \sqrt{\frac{f}{1{\cdot}226 w r}} \quad . \quad . \quad . \quad . \quad . \quad (59)$$

RULE 7.—To find *the weight*, when the centrifugal force, the angular velocity, and the radius of gyration are given. Multiply the square of the angular velocity by the radius of gyration, and by 1·226; divide the centrifugal by the product. Or,

$$w = \frac{f}{1{\cdot}226 v_1^2 r} \quad . \quad . \quad . \quad . \quad . \quad (60)$$

RULE 8.—To find *the radius of gyration*, when the weight, the angular velocity, and the centrifugal force are given. Multiply the weight by the square of the angular velocity, and by 1·226; and divide the centrifugal force by the product. Or,

$$r = \frac{f}{1{\cdot}226 w v_1^2} \quad . \quad . \quad . \quad . \quad . \quad (61)$$

## Work.

The English unit of work is one foot-pound.

The French unit is one kilogrammetre.

One kilogrammetre is equal to 7·233 foot-pounds.

One foot-pound is equal to ·1382 kilogrammetre.

One horse-power is equal to work done at the rate of 33,000 pounds lifted one foot high, or 33,000 foot-pounds, per minute; or to 550 foot-pounds per second; or to (33,000 × 60 = )1,900,000 foot-pounds per hour—nearly 2 millions.

One cheval-vapeur, or cheval (French horse-power) is equal to 75 kilogrammetres, or 542·5 foot-pounds, per second.

One cheval is equal to ·9863 horse-power.

One horse-power is equal to 1·0139 chevaux.

One kilogramme per cheval is equal to 2·235 pounds per horse-power.

One pound per horse-power is equal to ·447 kilogramme per cheval.

If the work of a horse-power, expressed in foot-pounds, be divided by 772, the quotient is the equivalent expression of horse-power in heat-units; or, $(33{,}000 \div 772 =) 42\frac{3}{4}$ heat-units per minute.

The work, known also as *vis viva*, done by gravity on a falling body is equal to the weight of the body multiplied by the height of the fall: the evidence of which is the velocity of motion acquired by the body.

The quantity of work stored in a body in motion is equal to the work which would be accumulated in it by gravity in falling from such a height as would suffice to generate the same velocity of motion. Consequently, the formulas proper for the action of gravity are applicable for calculations affecting bodies in motion, and the product of the height due to the velocity by the weight of the body, is expressive of the work stored in the body.

The height due to the velocity is equal to the square of the velocity divided by 64·4, according to formula (33), page 431, and as tabulated, page 434, and

$$U = \frac{wv^2}{64{\cdot}4} \quad . \quad . \quad . \quad . \quad . \quad (62)$$

$$\text{or } U = w \times h \quad . \quad . \quad . \quad . \quad . \quad . \quad (63)$$

$U$ = the work accumulated in the body, in foot-pounds.
$w$ = the weight of the body in pounds.
$v$ = the velocity of the body in feet per second.
$v_1$ = the angular velocity of a revolving body, in revolutions per second.
$v_{11}$ = the same in revolutions per minute.
$h$ = the height due to the velocity, in feet.
$r$ = the radius of gyration, in feet.

RULE 1.—To find the *work stored* in a moving body, given the weight of the body and the velocity. Multiply the weight of the body by the square of the velocity, and divide by 64·4.

RULE 2.—To find the *work stored* in a moving body, given the weight of the body, and the height due to the velocity. Multiply the weight by the height.

The work stored in a revolving body is calculated by either of the above rules, when linear velocity is given. But when the angular velocity is given, the equivalent to the linear velocity is found by substituting the expression $6{\cdot}2832 v_1 r_1$

already deduced, page 439, for $v$ in the formula (1), and reducing, thus :—

$$U = \cdot 613\, w v_1{}^2 r^2 \quad . \quad . \quad . \quad . \quad . \quad . \quad (64)$$

RULE 3.—To find the *work stored* in a revolving body, given the weight of the body, the angular velocity in revolutions per second, and the radius of gyration. Multiply the weight by the square of the angular volocity, and by the square of the radius of gyration, and by ·613.

When the angular velocity is given as the number of revolutions per minute, it is either to be divided by 60, before being brought into calculation, in accordance with the foregoing rule; or the expression $\frac{6{\cdot}2832\, v_1 r}{60}$ is to be substituted for $v$ in the formula (1), when the expression becomes,

$$U = \frac{w}{64{\cdot}4} \times \left(\frac{6{\cdot}2832 v_{11} r}{60}\right)^2, \text{ or reducing :—}$$

$$U = \cdot 00017 w v_{11}{}^2 r^2 \quad . \quad . \quad . \quad . \quad (65)$$

$$\text{or } U = \frac{w v_{11}{}^2 r^2}{5868} \quad . \quad . \quad . \quad . \quad . \quad . \quad (66)$$

RULE 4.—To find the *work stored* in a revolving body, given the weight of the body, the angular velocity in revolutions per minute, and the radius of gyration. Multiply the weight by the square of the angular velocity, by the square of the radius of gyration, and by ·00017.

RULE 5.—For the same purpose, proceed as in rule 4, except to divide by 5868, instead of multiplying by ·00017.

The work done by percussive force is simply measurable by the product of the weight of the colliding mass, and the height due to the velocity of the moment of impact plus the space moved through by the colliding mass after striking. Supposing that the blow be delivered fairly, without causing vibratory action, the work of resistance is equal to the work of impact. In the driving of a wedge, for instance, the product of the advance of the wedge by the resistance, cohesive and frictional, is equal to the work stored in the striking body. In the driving of a pile, similarly, the product of the frictional resistance by the advance of the pile under the blow of a ram is equal to the work stored in the ram. Of course, the stored work may to some extent be dissipated in vibratory action, leaving but a part of the stored work for useful performance.

## MILL GEARING, SHAFTING, &c.

### Driving Belts.

The ultimate tensile strength of leather belts of good quality, about ¼ inch thick, is about 1,000 pounds per inch of width. That of ordinary belts is about 750 pounds per inch of width. At laced junctions of ends of belts, the ultimate tensile strength is only about 200 pounds per inch of width. Taking Briggs and Towne's data, and assuming one-third of 200 pounds, or 66⅔ pounds per inch wide, as the maximum working stress, the Table 232 gives the driving power of leather belts.

TABLE 232.—DRIVING POWER OF LEATHER BELTS, ·22 INCH THICK. (Clark's *Manual*.)

| Arcs of Contact. | Maximum Working Stress transmitted per Inch Wide. | Power transmitted per Inch Wide. At One Foot per Second, Velocity of Belt. | Power transmitted per Inch Wide. Per Foot of Diameter of Pulley and per Turn per Minute. | | Sum of the Tensions on both Sides of a Belt per Inch Wide. | Resultant Pressure on the Journals per Inch Width of Belt. |
|---|---|---|---|---|---|---|
| Degrees. | Pounds. | H. P. | H. P. | Ft.-lbs. | Pounds. | Pounds. |
| 90 | 32·33 | ·059 | ·00308 | 102 | 101·00 | 71·42 |
| 100 | 34·80 | ·063 | ·00331 | 109 | 98·53 | 75·47 |
| 110 | 37·07 | ·067 | ·00353 | 116 | 96·26 | 78·85 |
| 120 | 39·18 | ·071 | ·00373 | 123 | 94·15 | 81·53 |
| 135 | 42·06 | ·076 | ·00400 | 132 | 91·27 | 84·32 |
| 150 | 44·64 | ·081 | ·00425 | 140 | 88·69 | 85·67 |
| 180 | 49·01 | ·089 | ·00467 | 154 | 84·32 | 84·32 |
| 210 | 52·52 | ·095 | ·00500 | 165 | 80·81 | 78·05 |
| 240 | 53·33 | ·100 | ·00527 | 174 | 78·00 | 67·59 |
| 270 | 57·58 | ·105 | ·00548 | 181 | 75·75 | 53·56 |

The Table 233 of the horse-power of belting is calculated for pulleys of nearly equal diameters, or which are well apart, allowing the belt to lap half round the smaller pulley.

Where the arc of contact is sensibly less than a semicircle, the tabular power transmitted is to be reduced in the same proportion.

The Table 233 is based on an allowance of 800 feet per minute travel of belting 1 inch width per horse-power; equivalent to about 41 lbs. tension per 1 inch width of belt.

TABLE 233.—DRIVING POWER OF LEATHER BELTS. (F. A. Halsey.)

| Diameter of Pulley. | Revolutions of the Pulley per Minute. | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 50 | 60 | 70 | 80 | 90 | 100 | 125 | 150 | 175 | 200 | 250 | 300 |
| | Horse-Power Transmitted by each Inch Wide of Single Belt. | | | | | | | | | | | |
| Inches. | H. P. | H. P. | H. P. | H. P. | H. P. | H. P. | H. P. | H. P. | H. P. | H. P. | H. P. | H. P. |
| 12 | ·20 | ·24 | ·28 | ·32 | ·35 | ·39 | ·49 | ·59 | ·69 | ·79 | ·98 | 1·18 |
| 14 | ·23 | ·28 | ·32 | ·37 | ·41 | ·46 | ·57 | ·69 | ·80 | ·92 | 1·14 | 1·38 |
| 16 | ·26 | ·32 | ·37 | ·42 | ·47 | ·53 | ·66 | ·79 | ·92 | 1·05 | 1·31 | 1·58 |
| 18 | ·30 | ·35 | ·41 | ·47 | ·53 | ·59 | ·74 | ·89 | 1·04 | 1·18 | 1·48 | 1·77 |
| 20 | ·33 | ·39 | ·46 | ·52 | ·59 | ·65 | ·82 | ·98 | 1·14 | 1·31 | 1·64 | 1·96 |
| 24 | ·39 | ·47 | ·55 | ·63 | ·71 | ·79 | ·98 | 1·18 | 1·38 | 1·58 | 1·97 | 2·36 |
| 28 | ·46 | ·55 | ·64 | ·73 | ·83 | ·92 | 1·15 | 1·38 | 1·61 | 1·84 | 2·29 | 2·75 |
| 32 | ·52 | ·63 | ·73 | ·84 | ·94 | 1·05 | 1·31 | 1·57 | 1·84 | 2·10 | 2·63 | 3·15 |
| 36 | ·59 | ·71 | ·83 | ·95 | 1·06 | 1·18 | 1·48 | 1·77 | 2·06 | 2·36 | 2·96 | 3·55 |
| 40 | ·65 | ·79 | ·92 | 1·04 | 1·18 | 1·31 | 1·64 | 1·96 | 2·29 | 2·62 | 3·27 | 3·94 |
| 44 | ·72 | ·87 | 1·01 | 1·15 | 1·30 | 1·45 | 1·80 | 2·16 | 2·53 | 2·89 | 3·60 | 4·34 |
| 48 | ·79 | ·94 | 1·10 | 1·26 | 1·42 | 1·57 | 1·96 | 2·36 | 2·75 | 3·15 | 3·93 | 4·72 |
| 54 | ·89 | 1·06 | 1·24 | 1·42 | 1·59 | 1·77 | 2·22 | 2·66 | 3·10 | 3·55 | 4·43 | 5·31 |
| 60 | ·98 | 1·18 | 1·38 | 1·57 | 1·77 | 1·96 | 2·46 | 2·95 | 3·44 | 3·93 | 4·91 | 5·90 |
| 66 | 1·08 | 1·30 | 1·52 | 1·73 | 1·95 | 2·17 | 2·71 | 3·25 | 3·79 | 4·33 | 5·41 | 6·50 |
| 72 | 1·18 | 1·42 | 1·65 | 1·89 | 2·13 | 2·36 | 2·95 | 3·54 | 4·13 | 4·72 | 5·90 | 7·10 |
| 78 | 1·28 | 1·53 | 1·79 | 2·04 | 2·30 | 2·56 | 3·20 | 3·84 | 4·48 | 5·11 | 6·40 | 7·68 |
| 84 | 1·38 | 1·65 | 1·93 | 2·21 | 2·48 | 2·75 | 3·44 | 4·13 | 4·81 | 5·51 | 6·89 | 8·28 |
| 90 | 1·48 | 1·77 | 2·06 | 2·36 | 2·66 | 2·96 | 3·68 | 4·43 | 5·18 | 5·90 | 7·38 | 8·85 |
| 96 | 1·57 | 1·89 | 2·21 | 2·53 | 2·84 | 3·15 | 3·95 | 4·73 | 5·51 | 6·31 | 7·89 | 9·45 |

### Rules for Speed of Belt-Pulleys.

To find the diameter of the driving pulley. Multiply the diameter of the driven pulley by the speed, or the number of revolutions it is to make per minute, and divide the product by the revolutions of the driving pulley per minute. The quotient is the diameter of the driver.

To find the diameter of the driven pulley. Multiply the diameter of the driving pulley by its speed, and divide the product by the speed of the driven pulley. The quotient is the diameter of the driven pulley.

To find the speed of the driven pulley. Multiply the diameter of the driving pulley by its speed; and divide the product by the diameter of the driven pulley. The quotient is the speed of the driven pulley.

### Weight of Belt-Pulleys (Clark's *Manual*).

Pulleys of from 1 foot to 4 feet in diameter, turned and finished; Midland district:—

$$W = 7d - 1{\cdot}75 \quad . \quad . \quad . \quad . \qquad (1)$$

$W$ = weight of pulley in pounds per inch wide.
$d$ = diameter, in feet.

This formula is probably applicable for pulleys of from 10 inches to 10 feet in diameter.

Pulleys of from 1 foot to 7 feet in diameter, turned and finished; London district:—

Not exceeding 2 feet in diameter $W = 3d^2 - {\cdot}625d + 2{\cdot}75$ (2)
2 feet and upwards „ $W = 11{\cdot}625d - 9{\cdot}25$ (3)

TABLE 234.—WEIGHT OF ROUND WROUGHT-IRON SHAFTING.

| Diameter of Shaft. | Weight per Lineal Foot | Diameter of Shaft. | Weight per Lineal Foot. | Diameter of Shaft. | Weight per Lineal Foot. | Diameter of Shaft. | Weight per Lineal Foot. |
|---|---|---|---|---|---|---|---|
| Inches. | Pounds. | Inches. | Pounds. | Inches. | Pounds. | Inches. | Pounds. |
| 1 | 2·62 | 2¾ | 19·8 | 5½ | 79·2 | 11 | 317 |
| 1¼ | 4·09 | 3 | 23·6 | 5¾ | 86·6 | 12 | 377 |
| 1½ | 5·89 | 3¼ | 27·7 | 6 | 94·2 | 13 | 398 |
| 1⅝ | 6·91 | 3½ | 32·1 | 6½ | 111 | 14 | 462 |
| 1¾ | 8·02 | 3¾ | 33·5 | 7 | 128 | 15 | 530 |
| 1⅞ | 9·20 | 4 | 41·9 | 7½ | 147 | 16 | 670 |
| 2 | 10·5 | 4¼ | 47·3 | 8 | 168 | 17 | 759 |
| 2⅛ | 11·8 | 4½ | 53·0 | 8½ | 189 | 18 | 848 |
| 2¼ | 13·3 | 4¾ | 59·1 | 9 | 212 | 19 | 945 |
| 2⅜ | 14·8 | 5 | 65·5 | 9½ | 236 | 20 | 1040 |
| 2½ | 16·4 | 5¼ | 72·2 | 10 | 262 | | |

*Note.*—To find the weight of steel shafting, multiply the tabular values by 1·02.

## TABLE 235.—HORSE-POWER OF SHAFTING.

| Diameter of the Shaft. | Speed or Revolutions per Minute. | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 50 | 60 | 70 | 80 | 90 | 100 | 125 | 150 | 175 | 200 | 250 | 300 |
| | Horse-Power transmitted by the Shaft. | | | | | | | | | | | |
| Inches. | H. P. | H. P. | H. P. | H. P. | H. P. | H. P. | H. P. | H. P. | H. P. | H. P. | H. P. | H. P. |
| 1 | ·40 | ·48 | ·56 | ·64 | ·72 | ·80 | 1·00 | 1·20 | 1·40 | 1·60 | 2·00 | 2·40 |
| 1¼ | ·78 | ·94 | 1·09 | 1·25 | 1·40 | 1·56 | 1·95 | 2·34 | 2·73 | 3·12 | 3·90 | 4·69 |
| 1½ | 1·35 | 1·62 | 1·89 | 2·16 | 2·43 | 2·70 | 2·87 | 4·05 | 4·72 | 5·40 | 6·75 | 8·10 |
| 1⅝ | 1·72 | 2·06 | 2·41 | 2·75 | 3·10 | 3·44 | 4·30 | 5·16 | 6·02 | 6·88 | 8·60 | 10·32 |
| 1¾ | 2·14 | 2·57 | 3·00 | 3·43 | 3·86 | 4·29 | 5·36 | 6·43 | 7·50 | 8·58 | 10·72 | 12·86 |
| 1⅞ | 2·64 | 3·17 | 3·70 | 4·23 | 4·76 | 5·27 | 6·59 | 7·91 | 9·23 | 10·55 | 13·19 | 15·82 |
| 2 | 3·20 | 3·84 | 4·48 | 5·12 | 5·76 | 6·40 | 8·00 | 9·60 | 11·20 | 12·80 | 16·00 | 19·20 |
| 2⅛ | 3·83 | 4·60 | 5·37 | 6·14 | 6·91 | 7·67 | 9·58 | 11·50 | 13·42 | 15·33 | 19·16 | 23·00 |
| 2¼ | 4·55 | 5·46 | 6·37 | 7·28 | 8·19 | 9·11 | 11·39 | 13·66 | 15·94 | 18·22 | 22·77 | 27·33 |
| 2⅜ | 5 36 | 6·43 | 7·50 | 8·57 | 9·64 | 10·72 | 13·40 | 16·08 | 18·76 | 21·44 | 26·80 | 32·16 |
| 2½ | 6·25 | 7·50 | 8·75 | 10·00 | 11·25 | 12·50 | 15·62 | 18·75 | 21·87 | 25·00 | 31·25 | 37·50 |
| 2¾ | 8·33 | 10·00 | 11·67 | 13·34 | 15·01 | 16·67 | 20·83 | 25·00 | 29·17 | 33·33 | 41·66 | 50·00 |
| 3 | 10·80 | 12·96 | 15·12 | 17·28 | 19·44 | 21·60 | 27·00 | 32·40 | 37·80 | 43·20 | 54·00 | 64·80 |
| 3¼ | 13·73 | 16·48 | 19·23 | 21·98 | 24·73 | 27·46 | 34·33 | 41·19 | 48·05 | 54·93 | 68·66 | 82·39 |
| 3½ | 17·15 | 20·58 | 24·01 | 27·44 | 30·87 | 34·30 | 42·88 | 51·45 | 60·03 | 68 60 | 85·75 | 102·90 |
| 3¾ | 21·09 | 25·31 | 29·53 | 33·75 | 37·97 | 42·17 | 52·71 | 63·25 | 73·79 | 84·33 | 105·42 | 126·50 |
| 4 | 25·60 | 30·72 | 35·84 | 40·96 | 46·08 | 51·20 | 64·00 | 76·80 | 89·60 | 102·40 | 128·00 | 153·60 |
| 4¼ | 30·71 | 36·85 | 42·99 | 49·13 | 55·27 | 61·41 | 76·76 | 92·12 | 107·47 | 122·82 | 153·53 | 184·23 |
| 4½ | 36·45 | 43·74 | 51·03 | 58·32 | 65·61 | 72·90 | 91·13 | 109·35 | 127·58 | 145·80 | 182·25 | 218·70 |
| 4¾ | 42·87 | 51·44 | 60·01 | 68·58 | 77·15 | 85·74 | 107·17 | 128·61 | 150·04 | 171·47 | 214·34 | 257·21 |
| 5 | 50·00 | 60·00 | 70·00 | 80·00 | 90·00 | 100·00 | 125·00 | 150·00 | 175·00 | 200·00 | 250·00 | 300·00 |
| 5¼ | 57·88 | 69·45 | 81·02 | 92·59 | 104·16 | 115·74 | 144·68 | 173·60 | 202·54 | 231·47 | 289·35 | 347·21 |
| 5½ | 66·55 | 79·86 | 93·17 | 106·48 | 119·79 | 133·12 | 166·39 | 199·68 | 233·96 | 266·24 | 332·79 | 399·36 |
| 5¾ | 76·04 | 91·25 | 106·46 | 121·67 | 136·88 | 152·08 | 190·10 | 228·12 | 266·14 | 304·16 | 380·20 | 456·24 |
| 6 | 86·40 | 103·68 | 120·96 | 138·24 | 155·52 | 172·80 | 216·00 | 259·20 | 302·40 | 345·60 | 432·00 | 518·40 |

## Horse-Power of Shafting.

The Table 235 is calculated by means of the formula :—

$$HP = \frac{d^3 \times t}{125} \quad . \quad . \quad . \quad . \quad (4)$$

HP = horse-power.
$d$ = diameter of shaft in inches.
$t$ = speed in turns per minute.

## Toothed Wheels.

The Table 236 of the driving power of toothed wheels is based on the formula :—

$$HP = \frac{p \times f \times d \times t}{850} \quad . \quad . \quad . \quad . \quad (5)$$

HP = horse-power transmitted.
$p$ = pitch in inches.
$f$ = width of face of teeth, in inches.
$d$ = diameter of wheel, in inches.
$t$ = turns per minute.

By this formula a pressure of about 150 pounds is exerted on the teeth of a wheel of 1 inch pitch and 1 inch face ; with a proportionate stress on teeth of other pitches.

## Weight of Cast-Iron Spur-Wheels of from 1 inch to 6 inches Pitch (Clark's *Manual*).

*Applicable for diameters up to 20 feet.*

$$W = (\cdot05 + \cdot08p)d \times (1 + \cdot10d) \quad . \quad . \quad (6)$$

W = weight of wheel per inch of face, in cwts.
$d$ = diameter in feet.
$p$ = pitch in inches.

## Weight of Cast-Iron Spur-Wheels of Pitches less than 1 inch.

Pitch.

$$\left.\begin{matrix}\frac{7}{8}\\ \frac{3}{4}\end{matrix}\right\} \quad W = \cdot0935d + \cdot0235d^2 \quad . \quad . \quad . \quad . \quad (7)$$

$$\frac{1}{2} \quad W = \cdot069d + \cdot0345d^2 \quad . \quad . \quad . \quad . \quad . \quad (8)$$

$$\frac{3}{8} \quad W = \cdot080d + \cdot0530d^2 \quad . \quad . \quad . \quad . \quad . \quad (9)$$

*Mortise Wheels* are of the same weight as spur-wheels of equal diameter.

*Bevil Wheels* and *Mitre Wheels* weigh from two-thirds to three-fourths of spur-wheels for the larger diameters, to about seven-eighths for the smaller diameters.

TABLE 236.—HORSE-POWER OF TOOTHED WHEELS. (F. A. Halsey.)

| Pitch of Teeth. | Diameter of Wheel in Inches. | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 6 | 9 | 12 | 15 | 18 | 21 | 24 | 30 | 36 | 42 | 48 | 54 | 60 | 72 | 84 | 96 | 108 | 120 |
| | Horse-Power per Revolution per Minute and per Inch of Face. | | | | | | | | | | | | | | | | | |
| Inches. | H.P. | H.P. | H.P. | H.P. | H.P. | H.P. | H.P. | H.P. | H.P. | H.P. | H.P. | H.P. | H.P. | H.P. | H.P. | H.P. | H.P. | H.P. |
| 1 | ·007 | ·011 | ·014 | ·018 | ·021 | ·025 | ·028 | ·035 | ·042 | ·049 | ·056 | ·064 | ·071 | ·085 | ·099 | ·113 | ·127 | ·141 |
| $1\frac{1}{4}$ | ·009 | ·013 | ·018 | ·022 | ·026 | ·031 | ·035 | ·044 | ·053 | ·062 | ·071 | ·079 | ·088 | ·106 | ·124 | ·141 | ·159 | ·176 |
| $1\frac{1}{2}$ | ·011 | ·016 | ·021 | ·026 | ·032 | ·037 | ·042 | ·053 | ·064 | ·074 | ·084 | ·095 | ·106 | ·127 | ·148 | ·169 | ·190 | ·212 |
| $1\frac{3}{4}$ | ... | ·019 | ·025 | ·031 | ·037 | ·043 | ·049 | ·062 | ·074 | ·086 | ·099 | ·111 | ·123 | ·148 | ·173 | ·198 | ·223 | ·247 |
| 2 | ... | ·021 | ·028 | ·035 | ·042 | ·049 | ·056 | ·071 | ·085 | ·097 | ·113 | ·127 | ·141 | ·169 | ·198 | ·226 | ·255 | ·282 |
| $2\frac{1}{4}$ | ... | ... | ·032 | ·040 | ·048 | ·056 | ·063 | ·079 | ·095 | ·111 | ·127 | ·143 | ·158 | ·191 | ·222 | ·255 | ·286 | ·318 |
| $2\frac{1}{2}$ | ... | ... | ·035 | ·044 | ·053 | ·062 | ·071 | ·088 | ·106 | ·123 | ·141 | ·159 | ·176 | ·212 | ·246 | ·283 | ·318 | ·353 |
| $2\frac{3}{4}$ | ... | ... | ... | ·049 | ·058 | ·068 | ·078 | ·097 | ·117 | ·136 | ·155 | ·175 | ·194 | ·233 | ·272 | ·311 | ·349 | ·388 |
| 3 | ... | ... | ... | ·053 | ·064 | ·074 | ·085 | ·106 | ·127 | ·148 | ·169 | ·191 | ·212 | ·254 | ·296 | ·338 | ·381 | ·423 |
| $3\frac{1}{4}$ | ... | ... | ... | ... | ·069 | ·080 | ·092 | ·115 | ·138 | ·160 | ·183 | ·206 | ·229 | ·275 | ·321 | ·367 | ·413 | ·459 |
| $3\frac{1}{2}$ | ... | ... | ... | ... | ·074 | ·086 | ·098 | ·123 | ·148 | ·173 | ·197 | ·222 | ·246 | ·296 | ·345 | ·395 | ·443 | ·493 |
| $3\frac{3}{4}$ | ... | ... | ... | ... | ·079 | ·093 | ·106 | ·132 | ·159 | ·185 | ·212 | ·238 | ·264 | ·318 | ·370 | ·423 | ·477 | ·529 |
| 4 | ... | ... | ... | ... | ... | ·098 | ·113 | ·141 | ·169 | ·197 | ·225 | ·254 | ·282 | ·338 | ·395 | ·451 | ·508 | ·564 |
| $4\frac{1}{2}$ | ... | ... | ... | ... | ... | ·111 | ·127 | ·159 | ·191 | ·223 | ·254 | ·286 | ·317 | ·381 | ·443 | ·510 | ·570 | ·633 |
| 5 | ... | ... | ... | ... | ... | ... | ·141 | ·176 | ·212 | ·247 | ·282 | ·318 | ·353 | ·423 | ·494 | ·565 | ·635 | ·705 |
| 6 | ... | ... | ... | ... | ... | ... | ·169 | ·211 | ·256 | ·296 | ·338 | ·381 | ·423 | ·509 | ·592 | ·679 | ·761 | ·846 |

TABLE 237.—TRANSMISSION OF POWER.
(Harpers.)

| Toothed Wheels (Double-flanged Wheel one-third more powerful). | | | | Steel Shafting. | | Single Belting. | | One Rope. | |
|---|---|---|---|---|---|---|---|---|---|
| Breadth of Teeth. | Pitch of Teeth. | Power that can be transmitted per 100 Feet of Circumferential Velocity per Minute. | | Diameter. | Power that can be transmitted per 10 Revolutions per Minute. | Breadth. | Power that can be transmitted for every 100 Feet of Velocity per Minute. | Diameter. | Power that can be transmitted for every 100 Feet of Velocity per Minute. |
| | | Spur. | Bevel. | | | | | | |
| Inches. | Inches. | H. P. | H. P. | Inches. | H. P. | Inches. | H. P. | Inches. | H. P. |
| 2 | 1 | $\frac{3}{8}$ | $\frac{1}{4}$ | $1\frac{1}{2}$ | $\frac{1}{2}$ | 3 | $\frac{3}{8}$ | $\frac{3}{4}$ | $\frac{1}{5}$ |
| 3 | $1\frac{1}{4}$ | $\frac{5}{8}$ | $\frac{1}{2}$ | 2 | $1\frac{1}{8}$ | 4 | $\frac{1}{2}$ | 1 | $\frac{1}{4}$ |
| 4 | $1\frac{1}{2}$ | $1\frac{1}{8}$ | $\frac{7}{8}$ | $2\frac{1}{2}$ | $2\frac{1}{4}$ | 5 | $\frac{5}{8}$ | $1\frac{1}{4}$ | $\frac{2}{5}$ |
| 5 | $1\frac{3}{4}$ | 2 | $1\frac{1}{2}$ | 3 | $3\frac{7}{8}$ | 6 | $\frac{3}{4}$ | $1\frac{1}{2}$ | $\frac{3}{5}$ |
| 6 | 2 | $3\frac{1}{8}$ | $2\frac{3}{8}$ | $3\frac{1}{2}$ | 6 | 7 | $\frac{7}{8}$ | $1\frac{3}{4}$ | $\frac{3}{4}$ |
| 7 | $2\frac{1}{4}$ | $4\frac{1}{2}$ | $3\frac{1}{2}$ | 4 | 9 | 8 | 1 | 2 | 1 |
| 8 | $2\frac{1}{2}$ | $6\frac{1}{4}$ | $4\frac{7}{8}$ | $4\frac{1}{2}$ | 13 | 9 | $1\frac{1}{8}$ | ... | ... |
| 9 | $2\frac{3}{4}$ | $8\frac{1}{2}$ | $6\frac{1}{2}$ | 5 | 18 | 10 | $1\frac{1}{4}$ | ... | ... |
| 10 | 3 | $11\frac{1}{4}$ | $8\frac{1}{2}$ | $5\frac{1}{2}$ | 24 | 12 | $1\frac{1}{2}$ | ... | ... |
| 11 | $3\frac{1}{4}$ | $14\frac{3}{4}$ | 11 | 6 | 31 | 15 | $1\frac{7}{8}$ | ... | ... |
| 12 | $3\frac{1}{2}$ | 19 | 14 | ... | ... | 18 | $2\frac{1}{4}$ | ... | ... |

### Friction-Wheel Gearing.

The grooves of friction-wheels are of **V** shape, forming the angle 50 degrees; usually at ⅜-inch pitch. Compared with leather belts, frictional gearing, worked under a pressure equal to the tension of the belts, has been proved to have greater adhesive force: 30 per cent. more, in one case.

### Transmission of Power (J. Bagshaw & Sons).

BELTING.—*To find the horse-power which can be transmitted by single leather belts.*—Multiply the breadth of belt in inches by 70, and by the speed of belt in feet per minute; and divide by 33,000. The quotient is the horse-power.

Double belts transmit 1½ times as much power as single belts.

*To find the width of single belt for transmitting a given horse-power.*—Multiply the horse-power by 33,000, and divide by 70 times the speed of the belt in feet per minute. The quotient is the width of belt in inches.

These rules are sufficiently approximate where there is no great degree of inequality in the diameters of the pulleys.

SHAFTING.—*To find the horse-power which can be transmitted by a wrought iron shaft.*—Multiply the cube of the diameter of the shaft in inches by the number of revolutions per minute, and divide by 80. The quotient is the horse-power.

*To find the diameter of a wrought iron shaft required to transmit a given horse-power.*—Multiply the horse-power by 80, and divide by the number of revolutions per minute. The cube root of the quotient is the diameter in inches.

ROPES.—*To find the horse-power that can be transmitted by ropes.*—Multiply the sectional area of one rope in square inches by 100 times the speed of the rope in feet per minute, and divide by 33,000. The quotient is the horse-power for one rope.

Or, multiply the sectional area of one rope by the speed, and divide by 330.

TOOTHED WHEELS.—*To find the horse-power that can be transmitted by toothed wheels.*—Multiply the velocity of the pitch-line in feet per second by the breadth of the teeth in inches, and by the square of the pitch in inches, and divide by 15. The quotient is the horse-power.

For bevel wheels, the mean diameter and mean pitch are to taken.

## Change-Wheels for Screw-Cutting Lathes.

(Richard Lloyd & Co.)

14 Pitch.—$\frac{3}{16}$ inch full, $\frac{5}{8}$ inch wide on face; suitable for 3-inch centre lathes. Number of teeth in each wheel, rising by one tooth from 15 to 75; thence, 77, 79, 80, 81, 82, 83, 84, 85, 87, 89, 90, 91, 92, 93, 94, 97, 99, 100, 101, 110, 120, 130, 140, 150, 180.

12 Pitch.—$\frac{1}{4}$ inch full, $\frac{13}{16}$ inch wide on face; suitable for 4-inch or 5-inch centre lathes. Teeth, rising by one tooth, from 15 to 40; thence, 42, 44, 45, 46, 48, 50, 52, 54, 55, 56, 58, 60, 65, 70, 75, 80, 85, 90, 95, 96, 100, 105, 110, 115, 120, 130, 140, 150.

10 Pitch.—$\frac{5}{16}$ inch, 1 inch wide; suitable for 6-inch or 7-inch centre lathes. Teeth rising by one tooth, from 15 to 25; thence, 26, 28, 30, 32, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, 100, 105, 110, 115, 120, 130, 140, 150, 160.

8 Pitch.—$\frac{3}{8}$ inch, $1\frac{1}{4}$ inch wide; suitable for 8-inch or 9-inch centre lathes. Teeth, rising by one tooth, from 15 to 20; thence, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 38, 40, 42, 44, 45, 46, 48, 50, 52, 54, 55, 56, 58, 60, 62, 63, 64, 65, 66, 68, 70, 72, 74, 75, 76, 78, 80, 85, 90, 95, 100, 105, 110, 115, 120, 130, 140, 150, 174, 200.

7 Pitch.—$\frac{7}{16}$ inch full, $1\frac{1}{2}$ inch wide; suitable for 10-inch to 12-inch centre lathes. Teeth, 15, 16, 18, 20, 22, 24, 25, 26, 28, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 88, 90, 95, 100, 105, 110, 115, 120, 130, 140, 150.

6 Pitch.—$\frac{1}{2}$ inch full, $1\frac{1}{2}$ inch wide; suitable for 12-inch to 15-inch centre lathes. Teeth, 15, 16, 17, 18, 19, 20, 22, 23, 25, 26, 28, 30, 32, 34, 35, 36, 38, 40, 42, 44, 45, 46, 48, 50, 52, 55, 60, 65, 70, 72, 75, 80, 85, 90, 95, 100, 105, 110, 115, 120, 150.

RULE I.—The pitch is calculated on the Manchester principle. Divide the number of teeth in the wheel by the diameter of the pitch-line. The quotient is the pitch.

RULE II.—The diameter is equal to the quotient of the number of teeth divided by the pitch.

The relations of the several factors are combined in the equation:—

$$ABC = DEF,$$

in which A is the number of threads per inch to be cut; B, the number of teeth in the wheel on the mandril; C, the number of teeth in the stud pinion; D, the number of threads per inch on the lead screw; E, the number of teeth in the wheel on the lead screw; F, the number of teeth in the stud wheel.

TABLE 238.—PITCH-LINE DIAMETERS OF
(Lister

| Number of Teeth. | PITCH IN $\frac{1}{4}$ | $\frac{3}{8}$ | $\frac{1}{2}$ | $\frac{5}{8}$ | $\frac{3}{4}$ | $\frac{7}{8}$ | 1 | $1\frac{1}{8}$ | $1\frac{1}{4}$ | $1\frac{1}{2}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ·08 | ·12 | ·1591 | ·1988 | ·2386 | ·2784 | ·3182 | ·3580 | ·3978 | ·4774 |
| 12 | ·95 | 1·43 | 1·91 | 2·38 | 2·86 | 3·34 | 3·82 | 4·28 | 4·77 | 5·73 |
| 13 | 1·05 | 1·55 | 2·07 | 2·58 | 3·10 | 3·62 | 4·14 | 4·64 | 5·17 | 6·21 |
| 14 | 1·11 | 1·67 | 2·23 | 2·78 | 3·34 | 3·90 | 4·46 | 4·99 | 5·57 | 6·68 |
| 15 | 1·19 | 1·79 | 2·39 | 2·98 | 3·58 | 4·18 | 4·77 | 5·35 | 5·97 | 7·16 |
| 16 | 1·29 | 1·91 | 2·55 | 3·18 | 3·82 | 4·48 | 5·09 | 5·70 | 6·37 | 7·64 |
| 17 | 1·35 | 2·03 | 2·70 | 3·38 | 4·06 | 4·73 | 5·41 | 6·06 | 6·77 | 8·12 |
| 18 | 1·43 | 2·15 | 2·86 | 3·58 | 4·30 | 5·01 | 5·73 | 6·42 | 7·17 | 8·60 |
| 19 | 1·51 | 2·27 | 3·02 | 3·78 | 4·54 | 5·29 | 6·05 | 6·78 | 7·56 | 9·08 |
| 20 | 1·59 | 2·38 | 3·18 | 3·98 | 4·77 | 5·57 | 6·36 | 7·13 | 7·96 | 9·55 |
| 21 | 1·67 | 2·50 | 3·34 | 4·18 | 5·05 | 5·85 | 6·68 | 7·49 | 8·36 | 10·02 |
| 22 | 1·75 | 2·64 | 3·50 | 4·38 | 5·25 | 6·12 | 7·00 | 7·85 | 8·76 | 10·50 |
| 23 | 1·85 | 2·74 | 3·66 | 4·58 | 5·49 | 6·40 | 7·32 | 8·25 | 9·16 | 10·98 |
| 24 | 1·91 | 2·86 | 3·82 | 4·77 | 5·73 | 6·68 | 7·64 | 8·56 | 9·55 | 11·46 |
| 25 | 1·98 | 2·98 | 3·97 | 4·98 | 5·97 | 6·96 | 7·96 | 8·29 | 9·96 | 11·94 |
| 30 | 2·38 | 3·58 | 4·77 | 5·96 | 7·16 | 8·35 | 9·55 | 10·70 | 11·93 | 14·32 |
| 35 | 2·78 | 4·17 | 5·57 | 6·96 | 8·35 | 9·25 | 11·14 | 12·73 | 14·27 | 15·91 |
| 40 | 3·18 | 4·97 | 6·36 | 7·95 | 9·54 | 11·14 | 12·73 | 14·27 | 15·91 | 19·10 |
| 45 | 3·58 | 5·37 | 7·16 | 8·91 | 10·14 | 12·53 | 14·32 | 16·05 | 17·90 | 21·40 |
| 50 | 3·98 | 5·96 | 7·96 | 9·94 | 11·93 | 13·92 | 15·91 | 17·83 | 19·89 | 23·87 |
| 55 | 4·37 | 6·56 | 8·75 | 10·94 | 13·12 | 15·32 | 17·50 | 19·62 | 21·88 | 26·26 |
| 60 | 4·77 | 7·16 | 9·55 | 11·93 | 14·32 | 16·71 | 19·09 | 21·40 | 23·87 | 28·64 |
| 65 | 5·17 | 7·75 | 10·34 | 12·93 | 15·51 | 18·10 | 20·68 | 23·19 | 25·86 | 31·03 |
| 70 | 5·57 | 8·35 | 11·14 | 13·92 | 16·70 | 19·49 | 22·27 | 24·97 | 27·85 | 33·42 |
| 75 | 5·96 | 8·94 | 11·93 | 14·92 | 17·89 | 20·89 | 23·86 | 26·75 | 29·84 | 35·81 |
| 80 | 6·36 | 9·54 | 12·73 | 15·91 | 19·09 | 22·28 | 25·46 | 28·54 | 31·82 | 38·19 |
| 85 | 6·76 | 10·14 | 13·52 | 16·90 | 20·28 | 23·67 | 27·05 | 30·32 | 33·81 | 40·58 |
| 90 | 7·16 | 10·73 | 14·32 | 17·90 | 21·47 | 25·06 | 28·64 | 32·19 | 35·80 | 42·97 |
| 95 | 7·55 | 11·34 | 15·11 | 18·89 | 22·68 | 26·45 | 30·23 | 33·89 | 37·79 | 45·36 |
| 100 | 7·95 | 11·93 | 15·91 | 19·89 | 23·86 | 27·85 | 31·82 | 35·67 | 39·78 | 47·74 |
| 110 | 8·75 | 13·12 | 17·50 | 21·88 | 26·24 | 30·63 | 35·00 | 39·24 | 43·76 | 52·51 |
| 120 | 9·54 | 14·31 | 19·09 | 23·87 | 28·63 | 33·42 | 38·18 | 42·81 | 47·74 | 55·70 |
| 130 | 10·34 | 15·51 | 20·68 | 25·86 | 31·02 | 36·20 | 41·36 | 46·37 | 51·72 | 62·06 |
| 140 | 11·13 | 16·75 | 22·27 | 27·85 | 33·40 | 38·99 | 44·54 | 49·94 | 55·70 | 66·84 |
| 150 | 11·93 | 17·89 | 23·86 | 29·83 | 35·79 | 41·77 | 47·73 | 53·51 | 59·67 | 71·61 |
| 160 | 12·72 | 19·09 | 25·45 | 31·87 | 38·18 | 44·56 | 50·91 | 57·08 | 63·65 | 75·38 |
| 170 | 13·52 | 20·28 | 27·04 | 33·81 | 40·56 | 47·34 | 54·10 | 60·64 | 67·63 | 81·16 |
| 180 | 14·32 | 21·47 | 28·64 | 35·80 | 42·95 | 50·13 | 57·28 | 64·21 | 71·60 | 85·93 |
| 190 | 15·11 | 22·66 | 30·23 | 37·79 | 45·33 | 52·91 | 60·46 | 67·78 | 75·58 | 90·71 |
| 200 | 15·91 | 23·86 | 31·82 | 39·78 | 47·72 | 55·70 | 63·64 | 71·35 | 79·56 | 95·48 |

| DECIMAL EQUIVALENTS | |
|---|---|
| | ·03125 = $\frac{1}{32}$ |
| | ·0625 = $\frac{1}{16}$ |
| | ·125 = $\frac{1}{8}$ |

TOOTHED WHEELS, CIRCULAR PITCH.

& Co.)

| Inches. | | | | | | | | | Number of Teeth |
|---|---|---|---|---|---|---|---|---|---|
| 1¾ | 2 | 2¼ | 2½ | 2¾ | 3 | 3¼ | 3½ | 4 | |
| ·5570 | ·6366 | ·7135 | ·7958 | ·8754 | ·9548 | 1·035 | 1·114 | 1·273 | 1 |
| 6·68 | 7·64 | 8·56 | 9·59 | 10·50 | 11·46 | 12·41 | 13·37 | 15·28 | 12 |
| 7·24 | 8·28 | 9·28 | 10·35 | 11·55 | 12·42 | 13·45 | 14·48 | 16·55 | 13 |
| 7·80 | 8·91 | 9·99 | 11·14 | 12·26 | 13·37 | 14·48 | 15·60 | 17·83 | 14 |
| 8·36 | 9·55 | 10·70 | 11·94 | 13·13 | 14·32 | 15·52 | 16·71 | 19·10 | 15 |
| 8·91 | 10·19 | 11·41 | 12·73 | 14·01 | 15·28 | 16·55 | 17·81 | 20·37 | 16 |
| 9·47 | 10·82 | 12·13 | 13·53 | 14·88 | 16·23 | 17·59 | 18·94 | 21·64 | 17 |
| 10·03 | 11·46 | 12·84 | 14·32 | 15·76 | 17·19 | 18·62 | 20·05 | 22·92 | 18 |
| 10·58 | 12·10 | 13·56 | 15·12 | 16·63 | 18·14 | 19·66 | 21·17 | 24·19 | 19 |
| 11·14 | 12·73 | 14·27 | 15·92 | 17·51 | 19·10 | 20·69 | 22·08 | 25·46 | 20 |
| 11·70 | 13·37 | 14·98 | 16·71 | 18·38 | 20·05 | 21·72 | 23·40 | 26·74 | 21 |
| 12·25 | 14·01 | 15·70 | 17·51 | 19·26 | 21·01 | 22·76 | 24·67 | 28·01 | 22 |
| 12·81 | 14·64 | 16·41 | 18·30 | 20·13 | 21·96 | 23·79 | 25·62 | 29·28 | 23 |
| 13·37 | 15·28 | 17·12 | 19·10 | 21·01 | 22·92 | 24·83 | 26·74 | 30·56 | 24 |
| 13·93 | 15·92 | 17·84 | 19·90 | 21·89 | 23·87 | 25·86 | 27·85 | 31·84 | 25 |
| 16·71 | 19·10 | 21·41 | 23·87 | 26·26 | 28·64 | 31·04 | 33·42 | 38·21 | 30 |
| 19·10 | 22·28 | 24·97 | 27·85 | 30·64 | 33·41 | 36·21 | 38·99 | 44·57 | 35 |
| 22·28 | 25·46 | 28·54 | 31·83 | 35·02 | 38·19 | 41·38 | 44·56 | 50·94 | 40 |
| 25·07 | 28·65 | 32·11 | 35·81 | 39·39 | 42·97 | 46·55 | 50·13 | 57·30 | 45 |
| 27·85 | 31·83 | 35·67 | 39·79 | 43·77 | 47·14 | 51·73 | 55·71 | 63·67 | 50 |
| 30·64 | 35·01 | 39·24 | 43·77 | 48·15 | 52·51 | 56·90 | 61·28 | 70·04 | 55 |
| 33·42 | 38·20 | 42·81 | 47·75 | 52·52 | 57·29 | 62·07 | 66·85 | 76·40 | 60 |
| 36·21 | 41·38 | 46·38 | 51·72 | 56·90 | 62·06 | 67·24 | 72·42 | 82·77 | 65 |
| 38·99 | 44·56 | 49·94 | 55·71 | 61·28 | 66·84 | 72·42 | 77·99 | 89·13 | 70 |
| 41·78 | 47·75 | 53·51 | 59·69 | 65·65 | 71·61 | 77·59 | 83·56 | 95·50 | 75 |
| 44·56 | 50·96 | 57·08 | 63·66 | 70·03 | 76·38 | 82·76 | 89·13 | 101·87 | 80 |
| 47·35 | 54·11 | 60·65 | 67·64 | 74·41 | 81·16 | 87·93 | 94·70 | 108·23 | 85 |
| 50·13 | 57·29 | 64·21 | 71·62 | 78·78 | 85·93 | 93·11 | 100·27 | 114·60 | 90 |
| 52·91 | 60·47 | 67·78 | 75·60 | 83·16 | 90·70 | 98·28 | 105·83 | 120·16 | 95 |
| 55·70 | 63·66 | 71·35 | 79·58 | 87·54 | 95·48 | 103·45 | 111·40 | 127·32 | 100 |
| 61·27 | 70·03 | 78·48 | 87·54 | 96·29 | 105·03 | 113·80 | 122·55 | 140·05 | 110 |
| 66·84 | 76·39 | 85·62 | 95·50 | 105·05 | 114·58 | 124·14 | 133·69 | 152·78 | 120 |
| 72·41 | 82·76 | 92·75 | 103·45 | 113·80 | 124·12 | 134·50 | 144·83 | 165·52 | 130 |
| 77·98 | 89·12 | 99·89 | 111·41 | 122·56 | 133·67 | 144·83 | 155·97 | 178·25 | 140 |
| 83·55 | 95·59 | 107·03 | 119·37 | 131·31 | 143·22 | 155·18 | 167·12 | 190·98 | 150 |
| 89·12 | 101·86 | 114·16 | 127·33 | 140·06 | 152·77 | 165·52 | 178·26 | 203·71 | 160 |
| 94·69 | 108·22 | 121·29 | 135·29 | 148·82 | 162·32 | 175·87 | 189·40 | 216·44 | 170 |
| 100·26 | 114·59 | 128·43 | 143·24 | 157·57 | 171·86 | 186·21 | 200·54 | 229·18 | 180 |
| 105·83 | 120·95 | 135·57 | 151·21 | 166·33 | 181·41 | 196·56 | 211·68 | 241·91 | 190 |
| 111·40 | 127·32 | 142·70 | 159·16 | 175·08 | 190·96 | 206·90 | 222·82 | 254·64 | 200 |

| | |
|---|---|
| ·25 = ¼ | ·625 = ⅝ |
| ·375 = ⅜ | ·75 = ¾ |
| ·5 = ½ | ·875 = ⅞ |

## TABLE 239.—WHEELS FOR DIVIDING WHEEL WITH 180 TEETH, SINGLE THREAD WORM.

(Lister & Co.)

| Divisions Required. | Wheel on Worm Shaft. | Wheel on Handle Shaft. | Turns of Handle. | Divisions Required. | Wheel on Worm Shaft. | Wheel on Handle Shaft. | Turns of Handle. | Divisions Required. | Wheel on Worm Shaft. | Wheel on Handle Shaft. | Turns of Handle. | Divisions Required. | Wheel on Worm Shaft. | Wheel on Handle Shaft. | Turns of Handle. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10 | 90 | 45 | 9 | 56 | 90 | 56 | 2 | 104 | 45 | 52 | 2 | 171 | 80 | 76 | 1 |
| 11 | 72 | 44 | 10 | 57 | 80 | 76 | 3 | 106 | 45 | 53 | 2 | 172 | 45 | 43 | 1 |
| 12 | 90 | 60 | 10 | 58 | 90 | 58 | 2 | 108 | 60 | 72 | 2 | 174 | 60 | 58 | 1 |
| 13 | 90 | 52 | 8 | 59 | 90 | 59 | 2 | 110 | 72 | 44 | 1 | 176 | 45 | 44 | 1 |
| 14 | 90 | 56 | 8 | 60 | 90 | 60 | 2 | 111 | 60 | 74 | 2 | 177 | 60 | 59 | 1 |
| 15 | 90 | 60 | 8 | 61 | 90 | 61 | 2 | 112 | 45 | 56 | 2 | 178 | 90 | 89 | 1 |
| 16 | 90 | 64 | 8 | 62 | 90 | 62 | 2 | 114 | 60 | 76 | 2 | 180 | 90 | 45 | ½ |
| 17 | 90 | 68 | 8 | 63 | 80 | 56 | 2 | 115 | 72 | 46 | 1 | 182 | 90 | 91 | 1 |
| 18 | 92 | 72 | 8 | 64 | 90 | 64 | 2 | 116 | 90 | 58 | 1 | 183 | 60 | 61 | 1 |
| 19 | 90 | 76 | 8 | 65 | 72 | 52 | 2 | 117 | 80 | 52 | 1 | 184 | 45 | 46 | 1 |
| 20 | 90 | 60 | 6 | 66 | 60 | 44 | 2 | 118 | 90 | 59 | 1 | 185 | 72 | 74 | 1 |
| 21 | 80 | 56 | 6 | 67 | 90 | 67 | 2 | 120 | 90 | 60 | 1 | 186 | 60 | 62 | 1 |
| 22 | 60 | 44 | 6 | 68 | 90 | 68 | 2 | 122 | 90 | 61 | 1 | 188 | 45 | 47 | 1 |
| 23 | 60 | 46 | 6 | 69 | 61 | 46 | 2 | 123 | 60 | 41 | 1 | 190 | 72 | 76 | 1 |
| 24 | 90 | 72 | 6 | 70 | 72 | 56 | 2 | 124 | 90 | 62 | 1 | 192 | 60 | 64 | 1 |
| 25 | 72 | 60 | 6 | 71 | 90 | 71 | 2 | 126 | 80 | 56 | 1 | 194 | 90 | 97 | 1 |
| 26 | 72 | 52 | 5 | 72 | 90 | 72 | 2 | 128 | 90 | 64 | 1 | 196 | 45 | 49 | 1 |
| 27 | 80 | 60 | 5 | 73 | 90 | 73 | 2 | 129 | 60 | 43 | 1 | 198 | 80 | 44 | ½ |
| 28 | 72 | 56 | 5 | 74 | 90 | 74 | 2 | 130 | 72 | 52 | 1 | 200 | 72 | 80 | 1 |
| 29 | 72 | 58 | 5 | 75 | 72 | 60 | 2 | 132 | 60 | 44 | 1 | 201 | 60 | 67 | 1 |
| 30 | 90 | 60 | 4 | 76 | 90 | 76 | 2 | 134 | 90 | 67 | 1 | 204 | 60 | 68 | 1 |
| 31 | 90 | 62 | 4 | 77 | 90 | 77 | 2 | 135 | 80 | 60 | 1 | 205 | 72 | 41 | ½ |
| 32 | 90 | 64 | 4 | 78 | 60 | 52 | 2 | 136 | 90 | 68 | 1 | 207 | 80 | 46 | ½ |
| 33 | 60 | 44 | 4 | 79 | 90 | 79 | 2 | 138 | 60 | 46 | 1 | 208 | 45 | 52 | 1 |
| 34 | 90 | 68 | 4 | 80 | 72 | 64 | 2 | 140 | 72 | 56 | 1 | 212 | 45 | 53 | 1 |
| 35 | 72 | 56 | 4 | 81 | 80 | 72 | 2 | 141 | 60 | 47 | 1 | 213 | 60 | 71 | 1 |
| 36 | 80 | 64 | 4 | 82 | 45 | 41 | 2 | 142 | 90 | 71 | 1 | 215 | 72 | 43 | ½ |
| 37 | 90 | 74 | 4 | 83 | 90 | 43 | 2 | 144 | 90 | 72 | 1 | 216 | 60 | 72 | 1 |
| 38 | 90 | 76 | 4 | 84 | 60 | 56 | 2 | 145 | 72 | 58 | 1 | 219 | 60 | 73 | 1 |
| 39 | 60 | 52 | 4 | 85 | 72 | 68 | 2 | 146 | 90 | 73 | 1 | 220 | 72 | 44 | ½ |
| 40 | 72 | 64 | 4 | 86 | 45 | 43 | 2 | 147 | 60 | 49 | 1 | 222 | 60 | 74 | 1 |
| 41 | 45 | 41 | 4 | 87 | 60 | 58 | 2 | 148 | 90 | 74 | 1 | 224 | 45 | 56 | 1 |
| 42 | 60 | 56 | 4 | 88 | 45 | 54 | 2 | 150 | 72 | 60 | 1 | 225 | 72 | 90 | 1 |
| 43 | 45 | 43 | 4 | 89 | 90 | 89 | 2 | 152 | 90 | 76 | 1 | 228 | 60 | 76 | 1 |
| 44 | 45 | 44 | 4 | 90 | 90 | 45 | 1 | 153 | 80 | 68 | 1 | 230 | 72 | 46 | ½ |
| 45 | 80 | 60 | 3 | 91 | 90 | 91 | 2 | 154 | 90 | 77 | 1 | 231 | 60 | 77 | 1 |
| 46 | 45 | 46 | 4 | 92 | 45 | 46 | 2 | 155 | 72 | 62 | 1 | 232 | 45 | 58 | 1 |
| 47 | 45 | 47 | 4 | 93 | 60 | 62 | 2 | 156 | 60 | 52 | 1 | 234 | 80 | 52 | ½ |
| 48 | 60 | 64 | 4 | 94 | 45 | 47 | 2 | 158 | 90 | 79 | 1 | 235 | 72 | 47 | ½ |
| 49 | 45 | 49 | 4 | 95 | 72 | 76 | 2 | 159 | 60 | 53 | 1 | 236 | 45 | 59 | 1 |
| 50 | 72 | 80 | 4 | 96 | 60 | 64 | 2 | 160 | 72 | 64 | 1 | 237 | 60 | 79 | 1 |
| 51 | 60 | 68 | 4 | 97 | 90 | 97 | 2 | 162 | 80 | 72 | 1 | 240 | 60 | 80 | 1 |
| 52 | 45 | 52 | 4 | 98 | 45 | 49 | 2 | 164 | 45 | 41 | 1 | 244 | 45 | 61 | 1 |
| 53 | 45 | 53 | 4 | 99 | 80 | 44 | 1 | 166 | 90 | 83 | 1 | 245 | 72 | 49 | ½ |
| 54 | 60 | 72 | 4 | 100 | 72 | 80 | 2 | 168 | 60 | 56 | 1 | 246 | 60 | 41 | ½ |
| 55 | 72 | 44 | 2 | 102 | 60 | 68 | 2 | 170 | 72 | 68 | 1 | 248 | 45 | 62 | 1 |

## Table 239.—Wheels for Dividing Wheel with 180 Teeth, Single Thread Worm (*continued*).

| Divisions Required. | Wheel on Worm Shaft. | Wheel on Handle Shaft. | Turns of Handle. | Divisions Required. | Wheel on Worm Shaft. | Wheel on Handle Shaft. | Turns of Handle. | Divisions Required. | Wheel on Worm Shaft. | Wheel on Handle Shaft. | Turns of Handle. | Divisions Required. | Wheel on Worm Shaft. | Wheel on Handle Shaft. | Turns of Handle. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 249 | 60 | 83 | 1 | 288 | 45 | 72 | 1 | 328 | 45 | 41 | ½ | 370 | 72 | 74 | ½ |
| 252 | 80 | 56 | ½ | 290 | 72 | 58 | ½ | 332 | 45 | 83 | 1 | 372 | 60 | 62 | ½ |
| 256 | 45 | 64 | 1 | 291 | 60 | 97 | 1 | 333 | 80 | 74 | ½ | 376 | 45 | 47 | ½ |
| 258 | 60 | 43 | ½ | 292 | 45 | 73 | 1 | 335 | 72 | 67 | ½ | 380 | 72 | 76 | ½ |
| 260 | 72 | 52 | ½ | 294 | 60 | 49 | ½ | 336 | 60 | 56 | ½ | 384 | 60 | 64 | ½ |
| 261 | 80 | 58 | ½ | 295 | 72 | 59 | ½ | 340 | 72 | 68 | ½ | 385 | 72 | 77 | ½ |
| 264 | 60 | 44 | ½ | 296 | 45 | 74 | 1 | 342 | 80 | 76 | ½ | 388 | 45 | 97 | ½ |
| 265 | 72 | 53 | ½ | 300 | 72 | 60 | ½ | 344 | 45 | 43 | ½ | 392 | 45 | 49 | ½ |
| 267 | 60 | 89 | 1 | 304 | 45 | 76 | 1 | 348 | 60 | 58 | ½ | 395 | 72 | 79 | ½ |
| 268 | 45 | 67 | 1 | 305 | 72 | 61 | ½ | 352 | 45 | 44 | ¼ | 396 | 80 | 44 | ¼ |
| 270 | 60 | 90 | 1 | 306 | 80 | 68 | ½ | 354 | 60 | 59 | ½ | 400 | 72 | 80 | ½ |
| 272 | 45 | 68 | 1 | 308 | 45 | 77 | 1 | 355 | 72 | 71 | ½ | 402 | 60 | 67 | ½ |
| 273 | 60 | 91 | 1 | 310 | 72 | 62 | ½ | 356 | 45 | 89 | 1 | 405 | 80 | 45 | ¼ |
| 276 | 60 | 46 | ½ | 312 | 60 | 52 | ½ | 360 | 45 | 90 | 1 | 408 | 60 | 68 | ½ |
| 279 | 80 | 62 | ½ | 316 | 45 | 79 | 1 | 364 | 45 | 91 | 1 | 410 | 72 | 41 | ¼ |
| 280 | 72 | 56 | ½ | 318 | 60 | 53 | ½ | 365 | 72 | 73 | ½ | 416 | 45 | 52 | ½ |
| 282 | 60 | 47 | ½ | 320 | 45 | 80 | 1 | 366 | 60 | 61 | ½ | 424 | 45 | 53 | ½ |
| 284 | 45 | 71 | 1 | 324 | 80 | 72 | ½ | 368 | 45 | 46 | ½ | 426 | 60 | 71 | ½ |

For a 90 Dividing Wheel, halve the turns or halve the handle shaft wheel, or double the worm shaft wheel.

For a 360 Dividing Wheel, double the turns or handle shaft wheel, or halve the worm shaft wheel.

This Table shows 256 different divisions cut by the use of 33 change wheels.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Change Wheels | 41 | 43 | 44 | 45 | 46 | 47 | 49 |
| | 52 | 53 | 54 | 56 | 58 | 59 | |
| | 60 | 61 | 62 | 64 | 67 | 68 | |
| | 71 | 72 | 73 | 74 | 74 | 77 | 79 |
| | 80 | 83 | 89 | 90 | 91 | 92 | 97 |

## Table 240.—Change Wheels, etc., for Dividing Wheel with 240 Teeth, Single Thread Worm.

(Lister & Co.)

| Number of Teeth. | Wheel on Worm Shaft. | Handle Shaft. | Turns. | Number of Teeth. | Wheel on Worm Shaft. | Handle Shaft. | Turns. | Number of Teeth. | Wheel on Worm Shaft. | Handle Shaft. | Turns. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A | B | C | D | A | B | C | D | A | B | C | D |
| 3 | 20 | 100 | 16 | 39 | 65 | 100 | 4 | 75 | 75 | 120 | 2 |
| 4 | 20 | 120 | 10 | 40 | 40 | 120 | 2 | 76 | 95 | 50 | 6 |
| 5 | 20 | 120 | 8 | 41 | 41 | 120 | 2 | 77 | 77 | 120 | 2 |
| 6 | 20 | 100 | 8 | 42 | 35 | 100 | 2 | 78 | 65 | 100 | 2 |
| 7 | 35 | 100 | 12 | 43 | 43 | 120 | 2 | 79 | 79 | 120 | 2 |
| 8 | 20 | 100 | 6 | 44 | 110 | 100 | 6 | 80 | 40 | 60 | 2 |
| 9 | 45 | 100 | 12 | 45 | 45 | 120 | 2 | 81 | 54 | 80 | 2 |
| 10 | 20 | 120 | 4 | 46 | 115 | 100 | 6 | 82 | 41 | 60 | 2 |
| 11 | 55 | 100 | 12 | 47 | 47 | 120 | 2 | 83 | 83 | 120 | 2 |
| 12 | 20 | 100 | 4 | 48 | 20 | 50 | 3 | 84 | 35 | 50 | 2 |
| 13 | 65 | 100 | 12 | 49 | 49 | 120 | 2 | 85 | 85 | 120 | 2 |
| 14 | 35 | 100 | 6 | 50 | 25 | 60 | 2 | 86 | 43 | 60 | 2 |
| 15 | 25 | 100 | 4 | 51 | 51 | 120 | 2 | 87 | 58 | 40 | 4 |
| 16 | 40 | 100 | 6 | 52 | 65 | 50 | 6 | 88 | 110 | 50 | 6 |
| 17 | 85 | 100 | 12 | 53 | 53 | 120 | 2 | 89 | 89 | 120 | 2 |
| 18 | 45 | 100 | 6 | 54 | 45 | 100 | 2 | 90 | 45 | 60 | 2 |
| 19 | 95 | 100 | 12 | 55 | 55 | 120 | 2 | 91 | 91 | 120 | 2 |
| 20 | 20 | 120 | 2 | 56 | 70 | 50 | 6 | 92 | 115 | 100 | 3 |
| 21 | 35 | 100 | 4 | 57 | 95 | 100 | 4 | 93 | 62 | 80 | 2 |
| 22 | 55 | 100 | 6 | 58 | 58 | 60 | 4 | 94 | 47 | 60 | 2 |
| 23 | 115 | 100 | 12 | 59 | 59 | 120 | 2 | 95 | 95 | 120 | 2 |
| 24 | 20 | 100 | 2 | 60 | 30 | 60 | 2 | 96 | 40 | 50 | 2 |
| 25 | 25 | 120 | 2 | 61 | 61 | 120 | 2 | 97 | 97 | 120 | 2 |
| 26 | 65 | 100 | 6 | 62 | 62 | 120 | 2 | 98 | 49 | 60 | 2 |
| 27 | 45 | 100 | 4 | 63 | 105 | 100 | 4 | 99 | 33 | 80 | 1 |
| 28 | 70 | 100 | 6 | 64 | 80 | 50 | 6 | 100 | 50 | 60 | 2 |
| 29 | 58 | 120 | 4 | 65 | 65 | 120 | 2 | 102 | 51 | 60 | 2 |
| 30 | 30 | 120 | 2 | 66 | 55 | 100 | 2 | 104 | 65 | 50 | 3 |
| 31 | 62 | 120 | 4 | 67 | 67 | 120 | 2 | 106 | 53 | 60 | 2 |
| 32 | 80 | 100 | 6 | 68 | 85 | 50 | 6 | 108 | 45 | 50 | 2 |
| 33 | 55 | 100 | 4 | 69 | 115 | 100 | 4 | 110 | 55 | 60 | 2 |
| 34 | 85 | 100 | 6 | 70 | 70 | 120 | 2 | 112 | 70 | 25 | 6 |
| 35 | 35 | 120 | 2 | 71 | 71 | 120 | 2 | 114 | 95 | 50 | 4 |
| 36 | 30 | 100 | 2 | 72 | 30 | 50 | 2 | 116 | 58 | 60 | 2 |
| 37 | 74 | 120 | 4 | 73 | 73 | 120 | 2 | 118 | 59 | 60 | 2 |
| 38 | 95 | 100 | 6 | 74 | 74 | 60 | 4 | 120 | 60 | 60 | 2 |

TABLE 240.—CHANGE WHEELS, ETC., FOR DIVIDING WHEEL WITH 240 TEETH, SINGLE THREAD WORM (*continued*).

| Number of Teeth. | Wheel on Worm Shaft. | Handle Shaft. | Turns. | Number of Teeth. | Wheel on Worm Shaft. | Handle Shaft. | Turns. | Number of Teeth. | Wheel on Worm Shaft. | Handle Shaft. | Turns. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A | B | C | D | A | B | C | D | A | B | C | D |
| 122 | 61 | 60 | 2 | 174 | 58 | 40 | 2 | 256 | 80 | 25 | 3 |
| 124 | 62 | 60 | 2 | 176 | 110 | 25 | 6 | 260 | 65 | 60 | 1 |
| 125 | 75 | 72 | 2 | 178 | 89 | 60 | 2 | 264 | 55 | 50 | 1 |
| 126 | 105 | 50 | 4 | 180 | 45 | 30 | 2 | 268 | 67 | 60 | 1 |
| 128 | 80 | 25 | 6 | 182 | 91 | 120 | 2 | 272 | 85 | 25 | 3 |
| 130 | 65 | 60 | 2 | 184 | 115 | 50 | 3 | 276 | 115 | 50 | 2 |
| 132 | 55 | 50 | 2 | 186 | 62 | 40 | 2 | 280 | 70 | 60 | 1 |
| 134 | 67 | 60 | 2 | 188 | 47 | 60 | 1 | 284 | 71 | 60 | 1 |
| 135 | 45 | 80 | 1 | 190 | 95 | 120 | 1 | 288 | 60 | 50 | 1 |
| 136 | 85 | 25 | 6 | 192 | 40 | 50 | 1 | 292 | 73 | 60 | 1 |
| 138 | 115 | 50 | 4 | 194 | 97 | 120 | 1 | 296 | 37 | 30 | 1 |
| 140 | 70 | 60 | 2 | 196 | 49 | 60 | 1 | 300 | 75 | 60 | 1 |
| 142 | 71 | 60 | 2 | 198 | 33 | 40 | 1 | 304 | 95 | 25 | 3 |
| 144 | 60 | 50 | 2 | 200 | 50 | 60 | 1 | 308 | 77 | 60 | 1 |
| 146 | 73 | 60 | 2 | 204 | 51 | 60 | 1 | 312 | 65 | 50 | 1 |
| 148 | 37 | 30 | 2 | 208 | 65 | 25 | 3 | 316 | 79 | 60 | 1 |
| 150 | 75 | 60 | 2 | 212 | 53 | 60 | 1 | 320 | 40 | 30 | 1 |
| 152 | 95 | 25 | 6 | 216 | 45 | 50 | 1 | 324 | 54 | 20 | 1 |
| 154 | 77 | 60 | 2 | 220 | 55 | 60 | 1 | 328 | 41 | 30 | 1 |
| 156 | 65 | 50 | 2 | 224 | 70 | 25 | 3 | 332 | 83 | 60 | 1 |
| 158 | 79 | 60 | 2 | 228 | 95 | 50 | 2 | 336 | 35 | 25 | 1 |
| 160 | 40 | 30 | 2 | 232 | 58 | 30 | 2 | 340 | 85 | 60 | 1 |
| 162 | 54 | 40 | 2 | 236 | 59 | 60 | 1 | 344 | 43 | 30 | 1 |
| 164 | 41 | 30 | 2 | 240 | 60 | 60 | 1 | 348 | 58 | 20 | 2 |
| 166 | 83 | 60 | 2 | 244 | 61 | 60 | 1 | 352 | 110 | 25 | 3 |
| 168 | 35 | 25 | 2 | 248 | 62 | 30 | 2 | 356 | 89 | 60 | 1 |
| 170 | 85 | 60 | 2 | 252 | 105 | 50 | 2 | 360 | 45 | 30 | 1 |
| 172 | 43 | 30 | 2 | | | | | | | | |

For a 120 Dividing Wheel, halve either the number of turns or the handle shaft wheel, or double the worm shaft wheel.

Column A = number of divisions required.
" B = " change wheels on worm shaft.
" C = " " on handle shaft.
" D = " turns to handle shaft.

# MILLING.

(Lister & Co.)

## Use of Cutters.

All cutters should be kept *sharp*. All cutters and arbors should run *true*. All arbors should be as *strong* as possible.

It is more satisfactory to run cutters up to *nearly* maximum speed, with a comparatively light feed, than to reduce the speed of the cutter and over feed the work; there being less stress upon the Machine, the Cutter, the Arbor, and the Work; and more accurate and better finished work being produced in the same time.

NOTE.—Care should be taken that in all cases the work should be fed *against* the cutter, in order to avoid the cutter dragging the work, and producing bad finish.

## Speed of Cutters.

This varies considerably with the kind of material operated upon, the intelligent workman will be called upon to use his judgment in the matter. We give a few average speeds for ordinary material; these may in some instances require to be reduced, in others considerably increased, as the material may be found to demand or admit. Work of a frail character, or requiring small cutters or small arbors, will necessitate a comparatively *light feed*, at the same time maintaining a good cutter speed.

AVERAGE CUTTING SPEEDS, PERIPHERY SPEED OF CUTTER (IN FEET) PER MINUTE.

| | Brass. | Wrought Iron. | Cast Iron. | Cast Steel. |
|---|---|---|---|---|
| Roughing . . . . | 80 | 40 | 30 | 20 |
| Finishing . . . . | 100 | 60 | 40 | 25 |
| Feed per min., inches | $2\frac{1}{2}''$ | $\frac{3}{4}''$ to $2''$ | $\frac{1}{2}''$ to $1\frac{1}{2}''$ | $\frac{1}{4}''$ to $\frac{1}{2}''$ |

The *rate of feed* will vary from $\frac{1}{50}''$ to $\frac{1}{16}''$ per foot of cutter speed, according to the strength of the work or the cutter and arbor, also the finish required and the material operated on. Thus, taking a 4" dia. of cutter, and maintaining the average cutting speed of 41 feet per minute (say 40 revolutions of cutter), the rate of feed may require to vary from $\frac{1}{2}''$ to $2\frac{1}{2}''$ per minute, according to the various conditions of the work and also the breadth of cut; as a rule, the broader the cutter and the deeper the cut the slower should be the feed, although this to a great extent depends upon the power and stability of the machine.

**Feeds in relation to Depth and Width of cut in ordinary cast iron, giving Revolutions of Cutter for one Inch of Feed.**

| Diameter of Cutters | 2" | | 3" | | 4" | | 6" | |
|---|---|---|---|---|---|---|---|---|
| Width of Cut . . | ½" | 2" | ½" | 2" | ½" | 2" | ½" | 2" |
| Revolutions, roughing ⅛" to ¼" deep | 45 | 40 | 30 | 25 | 25 | 22 | 15 | 12 |
| Finishing, $\frac{1}{64}$" deep. | 35 | 30 | 22 | 20 | 18 | 15 | 10 | 9 |

This will average for roughing $\frac{1}{20}$" feed of work to each 12" of cutter circumf. For finishing, $\frac{1}{16}$" or each 4" of cutter dia.

For broader cuts and harder material the number of revolutions per inch of feed will be increased.

### Cutters.

These should be made of high-class steel; some of the Sheffield houses will now undertake to harden any cutters made from their steel free of charge, and taking the risk.

The average pitch of teeth should be from ¼" to ⅜"; for ordinary cutters they should be radial on the face, that is, they should have little, if any, undercut. Cutters over 1" wide should be cut *spiral*, the spiral being about 20" pitch. Cutters from 3" to 5" dia. are best size for ordinary work.

For rapid wrought-iron milling it is advisable to direct a stream of oil or soap water on to the cutter by means of overhead sud tank or a pump.

### Milling Cutters compared with Shapers, Planes, &c.

Metal may be cut away by Milling Cutters at from 4 to 10 times the speed at which it can be cut by any ordinary tool such as a shaper, plane, &c., and in reciprocating machines the tool is only actually *cutting* during half the time, the period of reversing and return stroke being totally lost; again, the Milling Cutter will preserve its sharpness infinitely longer than single point tools. It has been proved in practice that Milling has an advantage over the Shaping Machine of at least 2 to 1 in plain work, up to 20 to 1 in duplicate and intricate work in point of time, and also in accuracy and finish.

### No. 2 Milling Machine.

The countershaft is provided with two loose pulleys 18' diameter to be driven from the main shaft by two belts, one belt driving the fast pulley 80 and the other 120 revolutions per minute, so that by moving the belt from the lower to the

higher speed, a suitable increase is made from roughing to finishing without altering the belt in the cones.

### TABLE OF SPEEDS.

| Step of Cone. | Revolutions per Minute. | Suitable for Cutters. | Speed of Countershaft. |
|---|---|---|---|
| No. 1 (large) | 18 | 9 to 10 dia. | 80 |
| | 20 | 7 to 8 ,, | 123 |
| No. 2 | 28 | 5 to 6 ,, | 80 |
| | 42 | 3 to 4 ,, | 120 |
| No. 3 | 56 | 2 to 2½ ,, | 80 |
| | 84 | 1¼ to 1¾ ,, | 123 |
| No. 4 (small) | 120 | 1 ,, | 80 |
| | 180 | ¾ ,, | 120 |

NOTE.—These speeds are *below* the *maximum*.

The speed of *High-speed* spindle through support arm ranges from 78 to 1,080 or to 4,000 revolutions per minute when driven direct without the long pulley.

SPIRALS.—A few general and useful pitches are given below. To gear for any other spiral, the following calculations will give the gears:—

The dividing wheel has 90 teeth; each turn of the hollow shaft in the knee moves the table ¼", so that 90 turns with equal gears will give a complete revolution to the dividing arbor, and a movement to the table of 22½"; this may be termed the natural pitch.

To obtain other pitches—*e.g.*, say we require a 10" pitch spiral, that is a complete revolution in 10" of length—multiply the pitch required by 4 to obtain the total turns of hollow shaft, the result divided by 90 gives the gear ratio, thus:—

$$\frac{10'' \times 4}{90} = \frac{40 \text{ on the spiral head}}{90 \text{ on the sliding shaft.}}$$

Required 15" pitch. $\left.\right\}\ \dfrac{15 \times 4}{90} = \dfrac{60 \text{ on the spiral head}}{90 \text{ on the sliding shaft}}$; and so on.

### USEFUL PITCHES.

| Angle of Cutter Spindle. | Pitch. Inches. | Wheel on Spiral Head. | Wheel on Sliding Shaft. | Suitable for |
|---|---|---|---|---|
| 20·30 | 3·75 | 20 | 120 | ¼" Twist Drill |
| 20·12 | 5· | 20 | 90 | ⅜" ,, ,, |
| 20·0 | 6·25 | 25 | 90 | ½" ,, ,, |
| 19·50 | 7·5 | 30 | 90 | ⅝" ,, ,, |
| 19·20 | 8·75 | 35 | 90 | 1" ,, ,, |
| 20·0 | 10·0 | 40 | 90 | 1¼" ,, ,, |
| | 22·5 | 60 | 60 | Spiral Cutters. |

## TRANSMISSION OF MOTIVE POWER TO GREAT DISTANCES.

### Transmission by Hemp Ropes.

For the driving gear of large steam engines, hemp ropes are much employed to take off the power from the circumference of the fly-wheel, which is grooved. The tension on the ropes is usually about 100lb. per square inch of section. The usual speed is from 4,500 to 5,500 feet per minute.

TABLE 241.—HORSE-POWER BY MANILLA ROPES. (Leavitt.)

| Speed of Rope, in Feet per Minute. | 1000 | 1500 | 2000 | 2500 | 3000 | 3500 | 4000 | 4500 | 5000 |
|---|---|---|---|---|---|---|---|---|---|
| Diameter of Rope. | Horse Power. | | | | | | | | |
| Inches. | | | | | | | | | |
| $\frac{3}{4}$ | $1\frac{3}{4}$ | $2\frac{3}{4}$ | $3\frac{1}{2}$ | $4\frac{1}{2}$ | $5\frac{1}{2}$ | $6\frac{1}{2}$ | 7 | $8\frac{1}{4}$ | 9 |
| 1 | $3\frac{1}{2}$ | $4\frac{7}{8}$ | $6\frac{1}{2}$ | 8 | 10 | 11 | 13 | 15 | 16 |
| $1\frac{1}{4}$ | $5\frac{1}{8}$ | $7\frac{1}{2}$ | $10\frac{1}{4}$ | 13 | 15 | 18 | 20 | 23 | 26 |
| $1\frac{1}{2}$ | $7\frac{1}{2}$ | 11 | 15 | 18 | 22 | 26 | 30 | 34 | 37 |
| $1\frac{3}{4}$ | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 |
| 2 | 13 | $19\frac{1}{2}$ | 26 | 33 | 39 | 46 | 52 | 59 | 65 |

### Transmission of Motive Power by Wire-Rope.

In one case, power was transmitted from a water-wheel through a horizontal distance of 400 feet by means of an iron wire-rope ·433 inch in diameter, which passed over two grooved cast-iron pulleys 6·56 feet in diameter, lined in the groove with compressed and tarred leather. The rope was formed of a central ply of Bologna hemp, tarred, around which were twisted six strands, each of eight iron wires, $\frac{1}{25}$ inch thick, on a core of tarred hemp. The speed was brought up by toothed gearing in two stages, so that the motor pulley made 19·04 turns for one of the water-wheel. For a speed of 96 turns per minute of the first intermediate shaft, the motor-pulley makes 145·85 turns, and the speed of its periphery is 50 feet per second, or 3000 feet per minute. At this speed, the loss by frictional resistance of the gearing and rope was 6·82 per cent.

### Transmission of Motive Power by Compressed Air.

The Paris Compressed Air Company supply air compressed by steam power, of 5 atmospheres pressure, to secondary engines of two types :—rotary engines for powers up to abo-

1 horse-power; and larger sized motors, up to double-cylinder engines having 12-inch cylinders with 14-inch stroke,—ordinary steam-engines employed for air. The secondary motor, when indicating 9·9 horse-power, and making 125 revolutions, according to Professor Kennedy, uses 890 cubic feet of air per indicator horse-power per hour. A small motor four miles distant from the central station, can indicate, in round numbers, 10 horse-power for 20 horse-power at the station, allowing for the value of the coke used in heating the air, or for 25 horse-power, if the air be not heated at all: making in the second instance an efficiency of 40 per cent.

**Transmission of Domestic Motive Power by Atmospheric Exhaustion.**

The distribution of power in dwelling-houses in Paris is effected by means of the exhaustion of air from a system of pipes, laid in the sewers for the most part, from which the power is supplied in small quantities to work the tools or machines employed in small industries. A vacuum, averaging 67 per cent. or 20 inches of mercury,—occasionally reaching to 75 per cent. or 22½ inches—is maintained in a reservoir, 49 inches in diameter, 11⅓ feet in length, serving to regulate the pressure in the service pipes. These are 10 inches and 8 inches in diameter, from the pumping station to the sewer, and 8 inches and 4 inches in the sewer or trench. The conduits do not exceed from 1 mile to 1¼ miles in length. The secondary motors are of the trunk type: supplying powers of from $\frac{1}{25}$th to 1 horse-power.

The air-cylinder utilises 93 per cent. of the engine-power transmitted. Of this the exhaust motors utilise a maximum of 60 per cent.; the loss of head in the main is 5 per cent.; lastly, the air yields only 85 per cent. of its total capacity for work. The resulting coefficient is 45 per cent.: and the actual work of 1 cubic foot of air is 1246 foot-pounds.

**Transmission of Motive Power by Electricity.**

This is easily effected, where the power does not exceed 30 horse-power, nor the distance 1¼ miles. In experiments by M. Fontaine, the dynamos made 1,200 revolutions per minute. The power delivered at the periphery of the fly-wheel of the steam engine was 95 horse-power; at the break, 50 horse-power; resistance of intermediate conductors (¼ inch copper wire, 77½ miles long), 100 ohms; 6,700 volts at origin of conducting line; intensity of current, 8 ampères; ultimate efficiency, 52·52 per cent.

In an experiment at the Munich Exhibition, in 1882, the generator was at Miesbach, and the electro-motor in the Exhibition palace, 35½ miles apart. The conductor was a

double line of iron telegraph wire, 4½ millimetres in diameter. The machines used were two similar Gramme dynamos, series wound. The resistance of each was 470 ohms, and that of the line 950 ohms, making the total resistance of circuit, $(950 + (470 \times 2)) = 1890$ ohms.

Generator, 1611 revolutions per minute; electromotive force = 1343 volts; current intensity = ·519 ampère.

Motor, 752 revolutions per minute; counter electromotive force = 850 volts.

$$\text{Theoretical efficiency} = \frac{850}{1343} = \cdot 63.$$

The power received at Munich was ½ horse-power; and the economical efficiency was about 25 per cent.

TABLE 242.—RESULTS OF TRIALS.

| | First Trial. | | Second Trial. | |
|---|---|---|---|---|
| | Generator. | Receiver. | Generator. | Receiver. |
| Speed in revolutions per minute | 190 | 248 | 120 | 277 |
| Electromotive force (direct or inverse). Volts | 5469 | 4242 | 5717 | 4441 |
| Current . Ampères | 7·21 | 7·21 | 7·20 | 7·20 |
| Work in magnetic field . H. P. | 9·20 | 3·75 | 10·30 | 3·80 |
| Electrical work in armature H. P. | 53·59 | 41·44 | 55·90 | 43·40 |
| Mechanical work measured in transmission dynamometer and at Prony break, H. P. | 62·10 | 35·80 | 61·00 | 40·00 |

Efficiency.

| | First Trial. | Second Trial. |
|---|---|---|
| | Per Cent. | Per Cent |
| Electric | 77·0 | 78·0 |
| Mechanical (commercial) | 47·7 | 53·4 |

See also *Hydraulic Transmission of Motive Power, post*, p. 603

# HEAT.

The British unit of heat, or thermal unit, is that which can raise the temperature of one pound of water 1 degree Fahrenheit, at or near 39°·1 F., the temperature of maximum density of water.

The French thermal unit, or *calorie*, is that which can raise the temperature of one kilogramme of water, 1 degree centigrade, at or about 4° C. (=39°·1 F.).

1 calorie, or French unit of heat, is equal to 3·968 British heat-units.

1 British heat-unit is equal to ·252 calorie.

The mechanical equivalent of one British heat-unit (Joule's equivalent) is 772 foot-pounds, or 10·67 kilogrammetres.

The mechanical equivalent of one French heat-unit is 425 kilogrammetres, or 3074 foot-pounds. If calculated in terms of Joule's equivalent, the value would be 423·55 kilogrammetres, or 3063·5 foot-pounds.

1 calorie per square metre is equal to ·369 heat-unit per square foot.

1 heat-unit per square foot is equal to 2·713 calories per square metre.

1 calorie per kilogramme is equal to 1·800 heat-units per pound.

1 heat-unit per pound is equal to ·556 calorie per kilogramme.

## Thermometers.

| | Freezing Point. | Boiling Point. |
|---|---|---|
| Fahrenheit thermometer | 32° | 212° |
| Centigrade ,, | 0° | 100° |
| Réaumur ,, | 0° | 80° |

1 degree Fahr. $=\frac{5}{9}$ Centigr. degree ; or $\frac{4}{9}$ Réaumur degree.
1 degree Centigr. $=\frac{9}{5}$ Fahr. degree ; or $\frac{4}{5}$ Réaumur degree.
1 degree Réaumur $=\frac{9}{4}$ Fahr. degree ; or $\frac{5}{4}$ Centigr. degree.

Representing the thermometric scales by their initials.

| | | |
|---|---|---|
| Equivalent temperature by the Centigrade scale | | $C. = \frac{5}{9}(F. - 32) = \frac{5}{4} R.$ |
| do. | by the Réaumur scale | $R. = \frac{4}{9}(F. - 32) = \frac{4}{5} C.$ |
| do. | by the Fahrenheit scale | $F. = \frac{9}{5} C. + 32 = \frac{9}{4} R. + 32.$ |

TABLE 243.—THERMOMETERS: FAHRENHEIT AND CENTIGRADE SCALES.

| Fahr. | Centigr. | Fahr. | Centigr. | Fahr. | Centigr. | Fahr. | Centigr. |
|---|---|---|---|---|---|---|---|
| ° | ° | ° | ° | ° | ° | ° | ° |
| 15 | −9·45 | 69 | 20·56 | 110 | 43·34 | 151 | 66·11 |
| 20 | −6·67 | 70 | 21·11 | 111 | 43·90 | 152 | 66·67 |
| 25 | −3·90 | 71 | 21·67 | 112 | 44·45 | 153 | 67·23 |
| 30 | −1·11 | 72 | 22·23 | 113 | 45·00 | 154 | 67·78 |
| 32 | 0·00 | 73 | 22·78 | 114 | 45·56 | 155 | 68·34 |
| 33 | +0·56 | 74 | 23·34 | 115 | 46·11 | 156 | 68·90 |
| 34 | 1·11 | 75 | 23·90 | 116 | 46·67 | 157 | 69·45 |
| 35 | 1·67 | 76 | 24·45 | 117 | 47·23 | 158 | 70·00 |
| 36 | 2·23 | 77 | 25·00 | 118 | 47·78 | 159 | 70·56 |
| 37 | 2·78 | 78 | 25·56 | 119 | 48·34 | 160 | 71·11 |
| 38 | 3·34 | 79 | 26·12 | 120 | 48·90 | 161 | 71·67 |
| 39 | 3·90 | 80 | 26·67 | 121 | 49·45 | 162 | 72·23 |
| 40 | 4·45 | 81 | 27·23 | 122 | 50·00 | 163 | 72·78 |
| 41 | 5·00 | 82 | 27·78 | 123 | 50·56 | 164 | 73·34 |
| 42 | 5·56 | 83 | 28·34 | 124 | 51·11 | 165 | 73·90 |
| 43 | 6·11 | 84 | 28·89 | 125 | 51·67 | 166 | 74·45 |
| 44 | 6·67 | 85 | 29·45 | 126 | 52·23 | 167 | 75·00 |
| 45 | 7·23 | 86 | 30·00 | 127 | 52·78 | 168 | 75·56 |
| 46 | 7·78 | 87 | 30·55 | 128 | 53·34 | 169 | 76·11 |
| 47 | 8·34 | 88 | 31·11 | 129 | 53·90 | 170 | 76·67 |
| 48 | 8·89 | 89 | 31·67 | 130 | 54·45 | 171 | 77·23 |
| 49 | 9·45 | 90 | 32·22 | 131 | 55·00 | 172 | 77·78 |
| 50 | 10·00 | 91 | 32·78 | 132 | 55·56 | 173 | 78·34 |
| 51 | 10·56 | 92 | 33·33 | 133 | 56·11 | 174 | 78·90 |
| 52 | 11·11 | 93 | 33·89 | 134 | 56·67 | 175 | 79·45 |
| 53 | 11·67 | 94 | 34·45 | 135 | 57·23 | 176 | 80·00 |
| 54 | 12·23 | 95 | 35·00 | 136 | 57·78 | 177 | 80·56 |
| 55 | 12·78 | 96 | 35·56 | 137 | 58·34 | 178 | 81·11 |
| 56 | 13·34 | 97 | 36·11 | 138 | 58·90 | 179 | 81·67 |
| 57 | 13·90 | 98 | 36·67 | 139 | 59·45 | 180 | 82·23 |
| 58 | 14·45 | 99 | 37·23 | 140 | 60·00 | 181 | 82·78 |
| 59 | 15·00 | 100 | 37·78 | 141 | 60·56 | 182 | 83·34 |
| 60 | 15·56 | 101 | 38·34 | 142 | 61·11 | 183 | 83·90 |
| 61 | 16·11 | 102 | 38·90 | 143 | 61·67 | 184 | 84·45 |
| 62 | 16·67 | 103 | 39·45 | 144 | 62·23 | 185 | 85·00 |
| 63 | 17·23 | 104 | 40·00 | 145 | 62·78 | 186 | 85·56 |
| 64 | 17·78 | 105 | 40·56 | 146 | 63·34 | 187 | 86·11 |
| 65 | 18·34 | 106 | 41·11 | 147 | 63·90 | 188 | 86·67 |
| 66 | 18·89 | 107 | 41·67 | 148 | 64·45 | 189 | 87·23 |
| 67 | 19·45 | 108 | 42·23 | 149 | 65·00 | 190 | 87·78 |
| 68 | 20·00 | 109 | 42·78 | 150 | 65·56 | 191 | 88·34 |

TABLE 243.—THERMOMETERS (*continued*).

| Fahr. | Centigr. | Fahr. | Centigr. | Fahr. | Centigr. | Fahr. | Centigr. |
|---|---|---|---|---|---|---|---|
| ° | ° | ° | ° | ° | ° | ° | ° |
| 192 | 88·90 | 222 | 105·56 | 310 | 154·45 | 460 | 237·78 |
| 193 | 89·45 | 223 | 106·11 | 315 | 157·23 | 465 | 240·56 |
| 194 | 90·00 | 224 | 106·67 | 320 | 160·00 | 470 | 243·34 |
| 195 | 90·56 | 225 | 107·23 | 325 | 162·78 | 475 | 246·11 |
| 196 | 91·11 | 226 | 107·78 | 330 | 165·56 | 480 | 248·90 |
| 197 | 91·67 | 227 | 108·83 | 335 | 168·34 | 485 | 251·67 |
| 198 | 92·23 | 228 | 108·90 | 340 | 171·11 | 490 | 254·45 |
| 199 | 92·78 | 229 | 109·45 | 345 | 173·90 | 495 | 257·23 |
| 200 | 93·34 | 230 | 110·00 | 350 | 176·67 | 500 | 260·00 |
| 201 | 93·90 | 232 | 111·11 | 355 | 179·45 | 505 | 262·78 |
| 202 | 94·45 | 234 | 112·23 | 360 | 182·23 | 510 | 265·56 |
| 203 | 95·00 | 236 | 113·34 | 365 | 185·00 | 515 | 268·34 |
| 204 | 95·56 | 238 | 114·45 | 370 | 187·78 | 520 | 271·11 |
| 205 | 96·11 | 240 | 115·56 | 375 | 190·56 | 525 | 273·90 |
| 206 | 96·27 | 242 | 116·67 | 380 | 193·34 | 530 | 276·67 |
| 207 | 97·23 | 244 | 117·78 | 385 | 196·11 | 535 | 279·45 |
| 208 | 97·78 | 246 | 118·90 | 390 | 198·90 | 540 | 282·23 |
| 209 | 98·34 | 248 | 120·00 | 395 | 201·67 | 545 | 285·00 |
| 210 | 98·90 | 250 | 121·11 | 400 | 204·45 | 550 | 287·78 |
| 211 | 99·45 | 255 | 123·90 | 405 | 207·23 | 555 | 290·56 |
| 212 | 100·00 | 260 | 126·67 | 410 | 210·00 | 560 | 293·34 |
| 213 | 100·56 | 265 | 129·45 | 415 | 212·78 | 565 | 296·11 |
| 214 | 101·11 | 270 | 132·23 | 420 | 215·56 | 570 | 298·90 |
| 215 | 101·67 | 275 | 135·00 | 425 | 218·34 | 575 | 301·67 |
| 216 | 102·23 | 280 | 137·78 | 430 | 221·11 | 580 | 304·45 |
| 217 | 102·78 | 285 | 140·56 | 435 | 223·90 | 585 | 307·23 |
| 218 | 103·34 | 290 | 1[illegible]·34 | 440 | 226·67 | 590 | 310·00 |
| 219 | 103·90 | 295 | 146·11 | 445 | 229·45 | 595 | 312·78 |
| 220 | 104·45 | 300 | 148·90 | 450 | 232·23 | 600 | 315·56 |
| 221 | 105·00 | 305 | 151·67 | 455 | 235·00 | | |

TABLE 244.—THERMOMETERS: CENTIGRADE AND FAHRENHEIT SCALES.

| Centigr. | Fahr. | Centigr. | Fahr. | Centigr. | Fahr. | Centigr. | Fahr. |
|---|---|---|---|---|---|---|---|
| ° | ° | ° | ° | ° | ° | ° | ° |
| −10 | 14·0 | 3 | 37·4 | 8 | 46·4 | 13 | 55·4 |
| −5 | 23·0 | 4 | 39·2 | 9 | 48·2 | 14 | 57·2 |
| 0 | 32·0 | 5 | 41·0 | 10 | 50·0 | 15 | 59·0 |
| +1 | 33·8 | 6 | 42·8 | 11 | 51·8 | 16 | 60·8 |
| 2 | 35·6 | 7 | 44·6 | 12 | 53·6 | 17 | 62·6 |

TABLE 244.—THERMOMETERS (*continued*).

| Centigr. | Fahr. | Centigr. | Fahr. | Centigr. | Fahr. | Centigr. | Fahr. |
|---|---|---|---|---|---|---|---|
| ° | ° | ° | ° | ° | ° | ° | ° |
| 18 | 64·4 | 60 | 140·0 | 102 | 215·6 | 158 | 316·4 |
| 19 | 66·2 | 61 | 141·8 | 103 | 217·4 | 160 | 320·0 |
| 20 | 68·0 | 62 | 143·6 | 104 | 219·2 | 162 | 323·6 |
| 21 | 69·8 | 63 | 145·4 | 105 | 221·0 | 164 | 327·2 |
| 22 | 71·6 | 64 | 147·2 | 106 | 222·8 | 166 | 330·8 |
| 23 | 73·4 | 65 | 149·0 | 107 | 224·6 | 168 | 334·4 |
| 24 | 75·2 | 66 | 150·8 | 108 | 226·4 | 170 | 338·0 |
| 25 | 77·0 | 67 | 152·6 | 109 | 228·2 | 172 | 341·6 |
| 26 | 78·8 | 68 | 154·4 | 110 | 230·0 | 174 | 345·2 |
| 27 | 80·6 | 69 | 156·2 | 111 | 231·8 | 176 | 348·8 |
| 28 | 82·4 | 70 | 158·0 | 112 | 233·6 | 178 | 352·4 |
| 29 | 84·2 | 71 | 159·8 | 113 | 235·4 | 180 | 356·0 |
| 30 | 86·0 | 72 | 161·6 | 114 | 237·2 | 182 | 359·6 |
| 31 | 87·8 | 73 | 163·4 | 115 | 239·0 | 184 | 363·2 |
| 32 | 89·6 | 74 | 165·2 | 116 | 240·8 | 186 | 366·8 |
| 33 | 91·4 | 75 | 167·0 | 117 | 242·6 | 188 | 370·4 |
| 34 | 93·2 | 76 | 168·8 | 118 | 244·4 | 190 | 374·0 |
| 35 | 95·0 | 77 | 170·6 | 119 | 246·2 | 192 | 377·6 |
| 36 | 96·8 | 78 | 172·4 | 120 | 248·0 | 194 | 381·2 |
| 37 | 98·6 | 79 | 174·2 | 121 | 249·8 | 196 | 384·8 |
| 38 | 100·4 | 80 | 176·0 | 122 | 251·6 | 198 | 388·4 |
| 39 | 102·2 | 81 | 177·8 | 123 | 253·4 | 200 | 392·0 |
| 40 | 104·0 | 82 | 179·6 | 124 | 255·2 | 202 | 395·6 |
| 41 | 105·8 | 83 | 181·4 | 125 | 257·0 | 204 | 399·2 |
| 42 | 107·6 | 84 | 183·2 | 126 | 258·8 | 206 | 402·8 |
| 43 | 109·4 | 85 | 185·0 | 127 | 260·6 | 208 | 406·4 |
| 44 | 111·2 | 86 | 186·8 | 128 | 262·4 | 210 | 410·0 |
| 45 | 113·0 | 87 | 188·6 | 129 | 264·2 | 212 | 413·6 |
| 46 | 114·8 | 88 | 190·4 | 130 | 266·0 | 214 | 417·2 |
| 47 | 116·6 | 89 | 192·2 | 132 | 269·6 | 216 | 420·8 |
| 48 | 118·4 | 90 | 194·0 | 134 | 273·2 | 218 | 424·4 |
| 49 | 120·2 | 91 | 195·8 | 136 | 276·8 | 220 | 428·0 |
| 50 | 122·0 | 92 | 197·6 | 138 | 280·4 | 222 | 431·6 |
| 51 | 123·8 | 93 | 199·4 | 140 | 284·0 | 224 | 435·2 |
| 52 | 125·6 | 94 | 201·2 | 142 | 287·6 | 226 | 438·8 |
| 53 | 127·4 | 95 | 203·0 | 144 | 291·2 | 228 | 442·4 |
| 54 | 129·2 | 96 | 204·8 | 146 | 294·8 | 230 | 446·0 |
| 55 | 131·0 | 97 | 206·6 | 148 | 298·4 | 232 | 449·6 |
| 56 | 132·8 | 98 | 208·4 | 150 | 302·0 | 234 | 453·2 |
| 57 | 134·6 | 99 | 210·2 | 152 | 305·6 | 236 | 456·8 |
| 58 | 136·4 | 100 | 212·0 | 154 | 309·2 | 238 | 460·4 |
| 59 | 138·2 | 101 | 213·8 | 156 | 312·8 | 240 | 464·0 |

TABLE 244.—THERMOMETERS (*continued*).

| Centigr. | Fahr. | Centigr. | Fahr. | Centigr. | Fahr. | Centigr. | Fahr. |
|---|---|---|---|---|---|---|---|
| ° | ° | ° | ° | ° | ° | ° | ° |
| 242 | 467·6 | 262 | 503·6 | 282 | 539·6 | 302 | 575·6 |
| 244 | 471·2 | 264 | 507·2 | 284 | 543·2 | 304 | 579·2 |
| 246 | 474·8 | 266 | 510·8 | 286 | 546·8 | 306 | 582·8 |
| 248 | 478·4 | 268 | 514·4 | 288 | 550·4 | 308 | 586·4 |
| 250 | 482·0 | 270 | 518·0 | 290 | 554·0 | 310 | 590·0 |
| 252 | 485·6 | 272 | 521·6 | 292 | 557·6 | 312 | 593·6 |
| 254 | 489·2 | 274 | 525·2 | 294 | 561·2 | 314 | 597·2 |
| 256 | 492·8 | 276 | 528·8 | 296 | 564·8 | 316 | 600·8 |
| 258 | 496·4 | 278 | 532·4 | 298 | 568·4 | 318 | 604·4 |
| 260 | 500·0 | 280 | 536·0 | 300 | 572·0 | 320 | 608·0 |

TABLE 245.—HIGH TEMPERATURES AND CORRESPONDING LUMINOSITY. (Pouillet.)

I. TEMPERATURE OF A FIRE.

| | Centigrade. | Fahrenheit. |
|---|---|---|
| | ° | ° |
| Nascent red | 525 | 977 |
| Dark red | 700 | 1292 |
| Nascent cherry red | 800 | 1472 |
| Cherry red | 900 | 1652 |
| Bright cherry red | 1000 | 1832 |
| Very deep orange | 1100 | 2012 |
| Bright orange | 1200 | 2192 |
| White | 1300 | 2372 |
| Dazzling white | 1500 | 2732 |

II. TEMPERATURE BY FUSION OF METALS, &C.

| Substance. | Temperature. | Metal. | Temperature. | Metal. | Temperature. |
|---|---|---|---|---|---|
| | Fahr. | | Fahr. | | Fahr. |
| | ° | | ° | | ° |
| Tallow | 92 | Bismuth | 518 | Silver, pure | 1830 |
| Spermaceti | 120 | Lead | 630 | Gold coin | 2156 |
| Wax, white | 154 | Zinc | 793 | Iron, cast, med. | 2010 |
| Sulphur | 239 | Antimony | 820 | Steel | 2550 |
| Tin | 455 | Brass | 1650 | Wrought iron | 2910 |

## Radiation of Heat.

The heat radiated from incandescent coal or coke is expressed by the formula :—

$$R = 144\, a^{\theta}\, (a^{t} - 1) \quad . \quad . \quad . \quad . \qquad (1)$$

$R$ = quantity of heat radiated per square foot of surface per hour, in British units.

$\theta$ = temperature of the enclosure, in Fahrenheit degrees.

$t$ = excess temperature of surface of hot body above the temperature of the enclosure, $\theta$, in Fahrenheit degrees.

$a$ = constant, 1·00425.

According to the formula, the rate of radiation increases in a much more rapid ratio than the excess temperature, when the temperature of the enclosure is constant.

The heat radiated from a coal or a coke fire, is estimated to be about one-half of the whole heat generated. It increases almost as fast as the rate of combustion of the fuel per hour per square foot.

## Convection of Heat, from an External Surface (Hopkins).

Surrounding Medium.

| | | |
|---|---|---|
| Air . . | $C = \cdot 2849t^{1\cdot 233}$ . . . . | (2) |
| Hydrogen . | $C = \cdot 9827t^{1\cdot 233}$ . . . . . | (3) |
| Carbonic acid . | $C = \cdot 2759t^{1\cdot 233}$ . . . . | (4) |
| Olefiant gas . | $C = \cdot 3817t^{1\cdot 233}$ . . . . . | (5) |

$C$ = quantity of heat, in English units, conveyed away from a solid body by a gas external to it, per square foot of surface per hour, under one atmosphere of pressure.

$t$ = excess temperature of surface in Fahrenheit degrees.

TABLE 246.—COMPARATIVE CONDUCTING POWER OF SOLIDS.

| Substance. | Comparative Power. | Substance. | Comparative Power. |
|---|---|---|---|
| | Gold = 1000. | | Gold = 1000. |
| Brass . . . | 749 | Platinum . . | 981 |
| Copper . . . | 892 | Porcelain . . | 12 |
| Gold . . . | 1000 | Silver . . . | 973 |
| Iron, cast . . | 562 | Terra Cotta . | 11 |
| ,, wrought . | 374 | Tin . . . | 304 |
| Lead . . . | 180 | Zinc . . . | 363 |
| Marble . . | 24 | | |

TABLE 247.—COMPARATIVE ABSORBING OR RADIATING AND REFLECTING PROPERTIES OF SOLIDS.

| Substance. | Absorbing or Radiating Power. | Reflecting Power. |
|---|---|---|
| | Proportion per Cent. | Proportion per Cent. |
| Brass, bright polished . . . | 7 | 93 |
| ,, dead polished . . | 11 | 89 |
| Copper. . . . . . . . | 7 | 93 |
| Glass . . . . . . . | 90 | 10 |
| Gold . . . . . . . . | 5 | 95 |
| Ice . . . . . . . . | 85 | 15 |
| Iron, cast, polished . . . | 25 | 75 |
| ,, wrought, polished . . | 23 | 77 |
| Marble . . . . . . . | 93 to 98 | 7 to 2 |
| Mercury . . . . . . . | 23 | 77 |
| Platinum, polished . . . | 24 | 76 |
| ,, sheet . . . . | 17 | 83 |
| Silverleaf on glass . . . | 27 | 73 |
| Silver, polished . . . . | 3 | 97 |
| Steel, polished . . . . . | 17 | 83 |
| Tin . . . . . . . . . | 15 | 85 |
| Water . . . . . . . . | 100 | 0 |
| Writing paper . . . . . | 98 | 2 |
| Zinc, polished . . . . . | 19 | 81 |

## Condensation of Steam in Bare Pipes exposed to Air.

Tredgold found that steam of 17½ lbs. absolute pressure per square was condensed in cast-iron pipes in a room at 60° F., at the rate of ·352 pound per square foot of exposed surface per hour; or ·0022 pound per degree of difference of temperature.

The following results were found by M. Clément. It is here assumed that the steam was of 20 lbs. absolute pressure per square inch. The pipes were exposed in a room at 77° F.

| Bare Surface. | Steam Condensed per Square Foot per Hour. |
|---|---|
| Cast-iron pipe, horizontal . . | ·328 lb. |
| Blackened ,, ,, . . . . | ·308 ,, |
| Copper ,, ,, . . | ·267 ,, |
| Blackened ,, ,, . . . . | ·308 ,, |
| ,, ,, upright . . | ·359 ,, |

M. Burnat found that for steam of 22 lbs. absolute pressure, with 196°·6 F. difference of temperature, ·581 lb. was condensed per square foot of a cast-iron pipe, nearly horizontal, per hour.

Dr. William Anderson experimented with a tubular steam heater, of 2-inch wrought-iron tubes, in a temperature of 59° F., with steam of 51 lbs. total pressure per square inch ·785 lb. was condensed per square foot per hour.

The foregoing results are collected in the following tablet :—

| Observer. | Temperature of surrounding Air. | Difference of Temperature. | Steam consumed per Square Foot per Hour. Total. | Steam consumed per Square Foot per Hour. Per 1° F. | Heat emitted per 1° F. difference of Temperature. |
|---|---|---|---|---|---|
| | ° Fahr. | ° Fahr. | Pound. | Pound. | Units. |
| Clement . | 77 | 151 | ·328 | ·00217 | 2·07 |
| Tredgold . | 60 | 161 | ·352 | ·0022 | 2·10 |
| Burnat . | 36·5 | 196·6 | ·581 | ·0030 | 2·81 |
| Anderson . | 59 | 223 | ·785 | ·0035 | 3·22 |

From these data, the following approximate formulæ are deduced :—

*Condensation of steam in cast-iron pipes, in air, per square foot of surface per hour at ordinary temperatures :—*

$$s = \frac{t^2}{55000} - \cdot 12 \quad . \quad . \quad . \quad . \quad . \quad (6)$$

*Heat emitted from cast-iron pipes, in air, per square foot of surface per hour, at ordinary temperatures :—*

$$h = \frac{t^2}{58} - 114 \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

*Heat emitted from cast-iron pipes, in air, per square foot of surface per degree of difference of temperature of steam and air, per hour, at ordinary temperatures.*

$$h' = \frac{t}{58} - \frac{114}{t} \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

$s$ = quantity of steam condensed in pounds.
$h$ = quantity of heat emitted in units.
$h'$ = quantity of heat emitted, per degree of difference of temperature.
$t$ = difference of temperature, in Fahrenheit degrees.

The latent heat of steam of 22 lbs. total pressure per square inch, 950 units per pound, is employed as the heat-factor, as an average value.

The Table 248 has been calculated by means of these formulas.

TABLE 248.—STEAM CONDENSED IN BARE CAST-IRON PIPES IN AIR, AND HEAT EMITTED, AT ORDINARY TEMPERATURES.

| Steam. | | Difference or Excess of Temperature of Steam above 62° Fahr. | Steam Condensed per Square Foot per Hour. | | Heat Emitted per Square Foot per Hour. | |
|---|---|---|---|---|---|---|
| Total Pressure per Square Inch. | Temperature. | | Total. | Per 1° F. of Difference. | Total. | Per 1° F. of Difference. |
| Pounds. | ° Fahr. | ° Fahr. | Lbs. | Pounds. | Units. | Units. |
| 14·7 | 212 | 150 | ·29 | ·00193 | 276 | 1·84 |
| 18 | 222 | 160 | ·346 | ·00216 | 329 | 2·05 |
| 21·5 | 232 | 170 | ·405 | ·00238 | 384 | 2·26 |
| 26 | 242 | 180 | ·47 | ·00261 | 446 | 2·48 |
| 31 | 252 | 190 | ·54 | ·00284 | 513 | 2·70 |
| 36·5 | 262 | 200 | ·607 | ·00303 | 577 | 2·89 |
| 43 | 272 | 210 | ·682 | ·00325 | 648 | 3·08 |
| 51 | 282 | 220 | ·76 | ·00345 | 722 | 3·28 |

For the increased rate of condensation induced by a draught of air, compared with that caused in the still air of a room, a bare steam boiler, in open air, was tested. Steam of 50 lbs absolute pressure per square inch was condensed at the rate of 1·25 pounds per square foot of external surface per hour; or, for a difference of 236° of temperature, ·0053 pound per degree of difference; showing that 4·79 units of heat per degree was emitted, or a half more than from a pipe in still air.

### Non-Conducting Coating for Steam Pipes.

M. Burnat's experiments were made with cast-iron steam pipes, 4·72 inches in diameter externally, ¼ inch thick, in a large unheated hall free from draughts. They were in five groups differently coated:—

1st group, coated with straw laid lengthwise, ·60 inch thick, ...ped with straw rope.

...oup, bare.

3rd group. Each pipe laid in a pottery pipe, enclosing an air-space, coated with a mixture of loamy earth and chopped straw, covered with tresses of straw.

4th group, coated with cotton-waste, 1 inch thick, wrapped in cloth bound with cord.

5th group, coated with a plaster of clay and cow's hair, 2·36 inches thick.

The results are given in Table 249.

TABLE 249.—CONDENSATION OF STEAM IN COATED PIPES. (Burnat.)

| Absolute Pressure of Steam per Square Inch. | Temperatures. | | | Steam condensed per Square Foot of External Surface of Pipes per Hour. | | | | |
|---|---|---|---|---|---|---|---|---|
| | Steam. | Air. | Difference. | Straw coat, 1st. | Bare, 2nd. | Pottery coat, 3rd. | Waste coat, 4th. | Plaster coat, 5th. |
| Lbs. | Fahr. | Fahr. | Fahr. | Lb. | Lb. | Lb. | Lb. | Lb. |
| 16·5 | 218·0 | 46·4 | 171·6 | ·139 | ·496 | ·170 | ·217 | ·254 |
| 16·5 | 218·0 | 33·8 | 184·2 | ·152 | ·485 | ·163 | ·205 | ·262 |
| 18·4 | 223·4 | 33·7 | 189·7 | ·164 | ·555 | ·186 | ·229 | ·287 |
| 18·4 | 223·4 | 27·1 | 196·4 | ·182 | ·571 | ·264 | ·287 | ·344 |
| 22·0 | 233·2 | 41·5 | 191·7 | ·246 | ·576 | ·258 | ·244 | ·320 |
| 22·0 | 233·2 | 36·5 | 196·7 | ·164 | ... | ·158 | ·250 | ... |
| 22·0 | 233·2 | 36·1 | 197·1 | ·162 | ·557 | ·178 | ·260 | ... |
| 22·0 | 233·2 | 28·9 | 204·3 | ·201 | ·586 | ·264 | ·328 | ·346 |
| 25·7 | 241·6 | 43·3 | 198·4 | ·244 | ·645 | ·301 | ·375 | ·389 |
| 25·7 | 241·6 | 36·5 | 205·1 | ·274 | ... | ·285 | ·369 | ... |
| 29·4 | 249·1 | 43·3 | 205·8 | ·252 | ·721 | ·270 | ·342 | ·379 |
| 29·4 | 249·1 | 30·6 | 218·4 | ·225 | ·621 | ·250 | ·328 | ·336 |
| Averages. 22·0 | 233·1 | 36·5 | 196·6 | ·200 | ·581 | ·229 | ·286 | ·324 |

The plaster coat, fifth group, was afterwards painted white, when an average of ·307 pound of steam was condensed per square foot per hour, against ·324 pound previously.

The bare pipe was afterwards coated with old felt, which had been treated with caoutchouc; and it condensed an average of ·313 pound of steam per square foot per hour.

The rates of condensation and of emission of heat are summarised as follows :—

TABLE 250.—SUMMARY RESULTS.

| Coating of Pipe. | Steam Condensed per Square Foot per Hour. | | Heat Emitted per Square Foot per Hour. | |
|---|---|---|---|---|
| | Total. | Per 1° F. Difference. | Total. | Per 1° F. Difference. |
| | Pound. | Pound. | Units. | Units. |
| Bare pipe | ·581 | ·00300 | 552·8 | 2·812 |
| Straw | ·200 | ·00102 | 190·3 | 0·968 |
| Pottery pipes with air-space | ·229 | ·00115 | 224·8 | 1·108 |
| Cotton waste | ·286 | ·00146 | 272·1 | 1·384 |
| Felt | ·313 | ·00159 | 297·8 | 1·515 |
| Plaster | ·324 | ·00165 | 308·3 | 1·568 |
| The same, painted white | ·307 | ·00156 | 292·1 | 1·486 |

**Cooling of Water in Pipes exposed to Air.**

Dr. Anderson experimented with 2-inch wrought-iron pipes, $\frac{3}{16}$ inch thick, galvanised, and 4-inch cast-iron pipes, $\frac{7}{16}$ inch thick, through which hot water was passed. Results are given in Table 251. The ultimate results harmonise with those for the use of steam in pipes.

TABLE 251.—COOLING OF WATER IN PIPES EXPOSED TO AIR.

| | Two-Inch Wrought-iron Pipes. | | | | Four-Inch Cast-iron Pipes. | | | |
|---|---|---|---|---|---|---|---|---|
| Number of experiment | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
| Temperature of the atmosphere Fahr. | 53° | 53° | 52°·5 | 52° | 60° | 60° | 60° | 59° |
| Average difference of temperatures of the water and the air. Fahr. | 103°·7 | 49°·4 | 25°·4 | 14°·3 | 62°·3 | 45°·8 | 33°·9 | 27°·3 |
| Total heat emitted per square foot per hour. Units | 233·7 | 104·4 | 46·45 | 19·7 | 99·5 | 69·9 | 49·5 | 38·2 |
| Heat emitted per 1° F. difference of temperature Units. | 2·25 | 2·11 | 1·83 | 1·39 | 1·59 | 1·53 | 1·46 | 1·40 |

Tredgold experimented with small vessels of different materials, in which water was cooled from a temperature of 180° to one of 159°, in a room at 58°. The heat emitted per square foot per hour per degree of mean difference of temperature was as follows:—

| | |
|---|---|
| Tin-plate . . . . . . | 1·37 units. |
| Sheet-iron . . . . . . | 2·24 ,, |
| Glass . . . . . . . | 2·18 ,, |

Also, in a $2\frac{1}{2}$ inch cast-iron pipe, $\frac{1}{4}$ inch thick, water was cooled from 152° to 140° F., in a room at 67°. The heat emitted per square foot per hour per degree of difference of temperature was as follows:—

| | |
|---|---|
| Ordinary rusty surface . . . | 1·823 units. |
| Black, varnished . . . . . | 1·900 ,, |
| White (two coats of lead paint). | 1·778 ,, |

## Transmission of Heat through Metal Plates from Water to Water.

In a metal tubular refrigerator, hot wort was cooled by water at such a rate that, taking averages, 80 units of heat passed from the wort, and was absorbed by the water per square foot of cooling surface per 1° F. per difference of temperature. The water and the wort were moved in opposite directions.

M. Péclet proved experimentally that the rate of transmission of heat was directly as the difference of temperature at the two faces of metal plates.

## Transmission of Heat through Metal Plates from Steam to Water.

The rate of transmission of heat from steam through a metal plate to water at the other side is practically uniform per degree of difference of temperature. The following Table gives average results of performance, from which it appears that the transmission is much more effective for evaporating than for heating water, twice as much for flat copper plate, three times as much for copper pipe, one-fourth more for cast-iron plate. Also, that pipe surface is one-fifth more effective than flat plate surface for heating, and more than twice as much for evaporation—the result of better circulation, no doubt.

TABLE 252.—HEATING AND EVAPORATING WATER BY STEAM THROUGH METALS.

| Metal Surface. | Per Square Foot per 1° F. difference of Temperature. | | | |
|---|---|---|---|---|
| | Steam Condensed. | | Heat Transmitted. | |
| | Heating. | Evaporating. | Heating. | Evaporating. |
| | Pounds. | Pounds. | Units. | Units. |
| Copper plate . . . | ·248 | ·483 | 276 | 534 |
| Copper pipe . . . | ·291 | 1·070 | 312 | 1034 |
| Cast-iron boiler . . | ·077 | ·105 | 82 | 100 |

Mr. Isherwood experimented with cylindrical metal-pots, 10 inches in diameter, $21\frac{1}{4}$ inches deep; $\frac{1}{8}$ inch, $\frac{1}{4}$ inch, and $\frac{3}{8}$ inch thick; turned and bored. They were placed in a steam-bath of from 220° to 320° F. Water at 212° was supplied to the pots, and evaporated. The rate of evaporation per degree of difference of temperature was the same for all temperatures; and the rate was the same for the different thicknesses. The respective weights of water, and heats consumed per square foot of inside surface, per degree of difference, were as follows:—

| | Water at 212°. | Heat. |
|---|---|---|
| Copper . . | ·665 lb. | 642·5 units. |
| Brass . . . | ·577 „ | 556·8 „ |
| Wrought-iron . | ·387 „ | 373·6 „ |
| Cast-iron . . | ·327 „ | 315·7 „ |

The differences of results for the same metal evidently arise in part from the comparative activity of circulation, and in part from the condition and position of the heating surfaces.

**Condensation of Steam in Pipes or Tubes by Water externally.**

From the results of experiments with surface-condensers, in which the steam was passed through the tubes, it appears that 500 units of heat by condensation were transmitted per square foot of tube surface per hour per 1° F. difference of temperature. The condensers were arranged in three groups of tubes successively traversed by the condensing water. In another case, where the condenser was arranged in two groups, from 220 to 240 units were transmitted.

Mr. B. G. Nichol experimented with an ordinary surface

condenser brass tube, $\frac{3}{4}$ inch in diameter outside, No. 18 wire-gauge in thickness; encased in a $3\frac{3}{4}$ inch iron pipe. Steam of $32\frac{1}{2}$ lbs. total pressure per square inch occupied the interspace, whilst cold water at 58° F. initial temperature was run through the brass tube. Three experiments were made with the tubes in a vertical position, and three in a horizontal position.

| | Vertical Position. | | | Horizontal Position. | |
|---|---|---|---|---|---|
| 1, | 2, | 3, | 4, | 5, | 6, |

Velocity of water through tube, in feet per minute,—

| | | | | | |
|---|---|---|---|---|---|
| 81, | 278, | 390, | 78, | 307, | 415 feet. |

Steam condensed per square foot of surface per hour, for 1° F. difference of temperature,—

| | | | | | |
|---|---|---|---|---|---|
| ·335, | ·436, | ·457, | ·480, | ·603, | ·699 lb. |

Heat absorbed by the water, per square foot per hour, per 1° F. difference of temperature,—

| | | | | | |
|---|---|---|---|---|---|
| 346, | 449, | 466, | 479, | 621, | 696 units. |

The rate of condensation was greater in the horizontal position than in the vertical position. Also, the efficiency of the condensing surface was increased by an increase of velocity of the water through the tube, nearly in the ratio of the fourth root of the velocity for vertical tubes; and nearly as the 4·5 root for horizontal tubes.

### Transmission of Heat through Metal Plates or Tubes, from Air or other Dry Gas to Water.

The rate of transmission of convected heat is probably from 2 to 5 units of heat per hour per square foot of surface per 1° F. of difference of temperature.

In a locomotive fire-box, where radiant heat co-operated with convected heat, the following results have been obtained in generating steam of 80 lbs. pressure per square inch. The temperature of the fire is taken at 2000° F.

| | Water Evaporated per Square Foot per Hour. | Heat Transmitted per Square Foot per Hour per 1° F. difference of Temperature. |
|---|---|---|
| Burning coke, 75 lbs. per square foot of grate . . . | $25\frac{1}{2}$ lbs. | $14\frac{1}{2}$ units |
| Burning briquettes, $74\frac{1}{2}$ lbs. per square foot of grate . . . | 35 " | 20 " |

There are in practice little or no differences between iron, copper, and lead in evaporative activity, when the surfaces are dimmed or coated, as under ordinary conditions.

TABLE 253.—LINEAL EXPANSION OF SOLIDS AT ORDINARY TEMPERATURES (Board of Trade).

| — | For 1° Fahr. | For 1° Cent. | Expansion between Freezing and Boiling Points. | | | |
|---|---|---|---|---|---|---|
| | | | Coefficient. | In length of Ten Feet. | | Common Fraction. |
| | Length = 1. | Length = 1. | | Foot. | Inch. | |
| Aluminium (cast) . . . . | ·00001234 | ·00002221 | ·002221 | ·02221 | ·2664 | $\frac{1}{450}$ |
| Antimony (cryst.) . . . . | ·00000627 | ·00001129 | ·001129 | ·01129 | ·1336 | $\frac{1}{885}$ |
| Brass, cast . . . . . . | ·00000957 | ·00001722 | ·001722 | ·01722 | ·2066 | $\frac{1}{581}$ |
| „ English plate . . . . | ·00001052 | ·00001894 | ·001894 | ·01894 | ·2273 | $\frac{1}{529}$ |
| „ sheet . . . . . . | ·00001040 | ·00001872 | ·001872 | ·01872 | ·2246 | $\frac{1}{535}$ |
| Brick, best stock . . . . . | ·00000306 | ·00000550 | ·000550 | ·00550 | ·0660 | $\frac{1}{1818}$ |
| Bronze (Baily's) . . . . . / Copper, 17 . . . . . . / Tin, $2\frac{1}{2}$ . . . . . . / Zinc, 1 . . . . . . . | ·00000986 | ·00001774 | ·001774 | ·01774 | ·2129 | $\frac{1}{563}$ |
| „ . . . . . . . . | ·00000975 | ·00001755 | ·001755 | ·01755 | ·2106 | $\frac{1}{565}$ |
| Cement, Roman, dry . . . . | ·00000797 | ·00001435 | ·001435 | ·01435 | ·1722 | $\frac{1}{694}$ |
| „ Portland (mixed), pure . | ·00000594 | ·00001070 | ·001070 | ·01070 | ·1284 | $\frac{1}{935}$ |
| „ „ mortar, with sand | ·00000656 | ·00001180 | ·001180 | ·01180 | ·1416 | $\frac{1}{847}$ |
| Concrete: cement mortar and pebbles . . . . . . | ·00000795 | ·00001430 | ·001430 | ·01430 | ·1716 | $\frac{1}{699}$ |
| Copper . . . . . . . | ·00000887 | ·00001596 | ·001596 | ·01596 | ·1915 | $\frac{1}{626}$ |
| Ebonite . . . . . . . | ·00004278 | ·00007700 | ·007700 | ·07700 | ·9240 | $\frac{1}{130}$ |

TABLE 253.—LINEAL EXPANSION OF SOLIDS AT ORDINARY TEMPERATURES (*continued*).

| ——— | For 1° Fahr. | For 1° Cent. | Expansion between Freezing and Boiling Points. | | | |
|---|---|---|---|---|---|---|
| | | | Coefficient. | In length of Ten Feet. | | Common Fraction. |
| | Length = 1. | Length = 1. | | Foot. | Inch. | |
| Glass, English flint | ·00000451 | ·00000812 | ·000812 | ·00812 | ·0974 | $\frac{1}{1234}$ |
| „ French flint | ·00000484 | ·00000872 | ·000892 | ·00892 | ·1070 | $\frac{1}{1121}$ |
| „ white, free from lead | ·00000492 | ·00000886 | ·000886 | ·00886 | ·1063 | $\frac{1}{1130}$ |
| „ blown | ·00000498 | ·00000896 | ·000896 | ·00896 | ·1075 | $\frac{1}{1111}$ |
| „ thermometer | ·00000499 | ·00000897 | ·000897 | ·00897 | ·1076 | $\frac{1}{1111}$ |
| „ hard | ·00000397 | ·00000714 | ·000714 | ·00714 | ·0857 | $\frac{1}{1400}$ |
| Granite, grey, dry | ·00000438 | ·00000789 | ·000789 | ·00789 | ·0947 | $\frac{1}{1266}$ |
| „ red „ | ·00000498 | ·00000897 | ·000897 | ·00897 | ·1076 | $\frac{1}{1111}$ |
| Gold, pure | ·00000786 | ·00001415 | ·001415 | ·01415 | ·1698 | $\frac{1}{707}$ |
| Iridium, pure | ·00000356 | ·00000641 | ·000641 | ·00641 | ·0768 | $\frac{1}{1562}$ |
| Iron, wrought | ·00000648 | ·00001166 | ·001166 | ·01166 | ·1399 | $\frac{1}{866}$ |
| „ Swedish | ·00000636 | ·00001145 | ·001145 | ·01145 | ·1374 | $\frac{1}{873}$ |
| „ cast | ·00000556 | ·00001001 | ·001001 | ·01001 | ·1201 | $\frac{1}{1000}$ |
| „ soft | ·00000626 | ·00001126 | ·001126 | ·01126 | ·1351 | $\frac{1}{897}$ |
| Lead | ·00001571 | ·00002828 | ·002828 | ·02828 | ·3394 | $\frac{1}{353}$ |
| Marble, moist | ·00000663 | ·00001193 | ·001193 | ·01193 | ·1432 | $\frac{1}{838}$ |
| „ dry | ·00000363 | ·00000654 | ·000654 | ·00654 | ·0785 | $\frac{1}{1530}$ |
| „ white Sicilian, dry | ·00000786 | ·00001415 | ·001415 | ·01415 | ·1698 | $\frac{1}{707}$ |

TABLE 253.—LINEAL EXPANSION OF SOLIDS AT ORDINARY TEMPERATURES (*continued*).

| — | For 1° Fahr. | For 1° Cent. | Expansion between Freezing and Boiling Points. | | | |
|---|---|---|---|---|---|---|
| | | | Coefficient. | In length of Ten Feet. | | Common Fraction. |
| | Length = 1. | Length = 1. | | Foot. | Inch. | |
| Marble, black Galway | ·00000308 | ·00000554 | ·000554 | ·00554 | ·0665 | $\frac{1}{1805}$ |
| " Carrara | ·00000471 | ·00000848 | ·000848 | ·00848 | ·1018 | $\frac{1}{1179}$ |
| Masonry, of brick in cement-mortar: headers | ·00000494 | ·00000890 | ·000890 | ·00890 | ·1068 | $\frac{1}{1123}$ |
| Do. do. stretchers | ·00000256 | ·00000460 | ·000460 | ·00460 | ·0552 | $\frac{1}{2174}$ |
| Mercury (cubic expansion) | ·00009984 | ·00017971 | ·017971 | ·17971 | 2·1565 | $\frac{1}{56}$ |
| Nickel | ·00000695 | ·00001251 | ·001251 | ·01251 | ·1501 | $\frac{1}{800}$ |
| Osmium | ·00000317 | ·00000570 | ·000570 | ·00570 | ·0684 | $\frac{1}{1754}$ |
| Palladium, pure | ·00000556 | ·00001000 | ·001000 | ·01000 | ·1200 | $\frac{1}{1000}$ |
| Pewter | ·00001129 | ·00002033 | ·002033 | ·02033 | ·2440 | $\frac{1}{494}$ |
| Plaster, white | ·00000922 | ·00001660 | ·001660 | ·01660 | ·1992 | $\frac{1}{602}$ |
| Platinum | ·00000479 | ·00000863 | ·000863 | ·00863 | ·1036 | $\frac{1}{1159}$ |
| Platinum, 90 per cent Iridium, 10 per cent. hammered and annealed | ·00000476 | ·00000857 | ·000857 | ·00857 | ·1028 | $\frac{1}{1167}$ |
| Platinum, 85 per cent. Iridium, 15 per cent. | ·00000453 | ·00000815 | ·000815 | ·00815 | ·0978 | $\frac{1}{1227}$ |
| Porcelain | ·00000200 | ·00000360 | ·000360 | ·00360 | ·0432 | $\frac{1}{2778}$ |

TABLE 253.—LINEAL EXPANSION OF SOLIDS AT ORDINARY TEMPERATURES (*continued*).

| —— | For 1° Fahr. | For 1° Cent. | Expansion between Freezing and Boiling Points. | | | |
|---|---|---|---|---|---|---|
| | | | Coefficient. | In length of Ten Feet. | | Common Fraction. |
| | Length = 1. | Length = 1. | | Foot. | Inch. | |
| Quartz, parallel to major axis, $t$ 0° to 40° C. | ·00000434 | ·00000781 | ·000781 | ·00781 | ·0937 | $\frac{1}{1280}$ |
| „ perpendicular to major axis, $t$ 0° to 40° C. | ·00000788 | ·00001419 | ·001419 | ·01419 | ·1703 | $\frac{1}{704}$ |
| „ cubic expansion at 16° C. | ·00001924 | ·00003463 | ·003463 | ·03463 | ·4155 | $\frac{1}{289}$ |
| Silver, pure | ·00001079 | ·00001943 | ·001943 | ·01943 | ·2334 | $\frac{1}{517}$ |
| Slate | ·00000577 | ·00001038 | ·001038 | ·01038 | ·1246 | $\frac{1}{967}$ |
| Steel, cast | ·00000636 | ·00001144 | ·001144 | ·01144 | ·1373 | $\frac{1}{874}$ |
| „ tempered | ·00000689 | ·00001240 | ·001240 | ·01240 | ·1488 | $\frac{1}{806}$ |
| Stone (sandstone), dry | ·00000652 | ·00001174 | ·001174 | ·01174 | ·1409 | $\frac{1}{852}$ |
| „ „ Rauville | ·00000417 | ·00000750 | ·000750 | ·00750 | ·0900 | $\frac{1}{1333}$ |
| „ „ Caen | ·00000494 | ·00000890 | ·000890 | ·00890 | ·1068 | $\frac{1}{1124}$ |
| Tin | ·00001163 | ·00002094 | ·002094 | ·02094 | ·2513 | $\frac{1}{477}$ |
| Wedgwood ware | ·00000489 | ·00000881 | ·000881 | ·00881 | ·1057 | $\frac{1}{1136}$ |
| Wood, pine | ·00000276 | ·00000496 | ·000496 | ·00496 | ·0595 | $\frac{1}{2016}$ |
| Zinc | ·00001407 | ·00002532 | ·002532 | ·02532 | ·3038 | $\frac{1}{395}$ |
| Zinc, 8 / Tin, 1 | ·00001496 | ·00002692 | ·002692 | ·02692 | ·3230 | $\frac{1}{372}$ |

### Comparative Rate of Emission of Heat from Steam Pipes in Air and in Water.

It appears that for equal total difference of temperature, the rate of emission of heat from steam pipes in water amounts, in round numbers, to from 150 to 250 times the rate in air, according as the pipes are vertical or horizontal.

### Comparative Rate of Emission of Heat from Water-Tubes in Air and in Water at Rest and in Motion.

It appears that the rate of emission from water-tubes in water was about twenty times the rate in air. Mr. Craddock proved it experimentally to be twenty-five times. When the water-tube was moved through the air at a speed of 59 feet per second, it was cooled in one-twelfth of the time occupied in still air. In water, moved at a speed of 3 feet per second, the water in the tube was cooled in half the time.

### Expansion of Liquids.

The cubical expansion, or expansion of volume, of water, from 32° F. to 212° F. and upwards, is given in Table 252. The rate of expansion increases with the temperature. The expansion for the range of temperature from 32° to 212° is ·0466, or fully $4\frac{1}{2}$ per cent. of the volume at 32°; or an average of ·000259 per degree, or $\frac{1}{3863}$ part of the volume at 32° F.

TABLE 254.—EXPANSION OF LIQUIDS, FROM 32° TO 212° F. Volume at 32° = 1.

| Liquid. | Volume at 212°. | Expansion. | Liquid. | Volume at 212°. | Expansion. |
|---|---|---|---|---|---|
| Alcohol | 1·1100 | $\frac{1}{9}$ | Sea water | 1·0500 | $\frac{1}{20}$ |
| Nitric acid | 1·1100 | $\frac{1}{9}$ | Water | 1·0466 | $\frac{1}{21}$ |
| Olive oil | 1·0800 | $\frac{1}{12}$ | Mercury | 1·018 | $\frac{1}{56}$ |
| Turpentine | 1·0700 | $\frac{1}{14}$ | | | |

TABLE 255.—EXPANSION AND WEIGHT OF WATER AT VARIOUS TEMPERATURES.

| Temperature. | Relative Volume by Expansion. | Weight of One Cubic Foot. | Weight of One Gallon. |
|---|---|---|---|
| ° Fahr. | | Pounds. | Pounds. |
| 32 | 1·00000 | 62·418 | 10·0101 |
| 35 | ·99993 | 62·422 | 10·0103 |
| 39·1 | ·99989 | 62·425 maximum density | 10·0112 |
| 40 | ·99989 | 62·425 | 10·0112 |
| 45 | ·99993 | 62·422 | 10·0103 |
| 46 | 1·00000 | 62·418 | 10·0101 |
| 50 | 1·00015 | 62·409 | 10·0087 |
| 52·3 | 1·00029 | 62·400 ordinary calculations. | 10·0072 |
| 55 | 1·00038 | 62·394 | 10·0063 |
| 60 | 1·00074 | 62·372 | 10·0053 |
| 62 mean temperature | 1·00101 | 62·355 | 10·0000 |
| 65 | 1·00119 | 62·344 | 9·9982 |
| 70 | 1·00160 | 62·313 | 9·9933 |
| 75 | 1·00239 | 62·275 | 9·9871 |
| 80 | 1·00299 | 62·232 | 9·980 |
| 85 | 1·00379 | 62·182 | 9·972 |
| 90 | 1·00459 | 62·133 | 9·964 |
| 95 | 1·00554 | 62·074 | 9·955 |

| Temperature. | Relative Volume by Expansion. | Weight of One Cubic Foot. | Weight of One Gallon. |
|---|---|---|---|
| ° Fahr. | | Pounds. | Pounds. |
| 100 | 1·00639 | 62·022 | 9·947 |
| 105 | 1·00739 | 61·960 | 9·937 |
| 110 | 1·00889 | 61·868 | 9·922 |
| 115 | 1·00989 | 61·807 | 9·913 |
| 120 | 1·01139 | 61·715 | 9·897 |
| 125 | 1·01239 | 61·654 | 9·887 |
| 130 | 1·01390 | 61·563 | 9·873 |
| 135 | 1·01539 | 61·472 | 9·859 |
| 140 | 1·01690 | 61·381 | 9·844 |
| 145 | 1·01839 | 61·291 | 9·829 |
| 150 | 1·01989 | 61·201 | 9·815 |
| 155 | 1·02164 | 61·096 | 9·799 |
| 160 | 1·02340 | 60·991 | 9·781 |
| 165 | 1·02589 | 60·843 | 9·757 |
| 170 | 1·02690 | 60·783 | 9·748 |
| 175 | 1·02906 | 60·665 | 9·728 |
| 180 | 1·03100 | 60·548 | 9·711 |
| 185 | 1·03300 | 60·430 | 9·691 |
| 190 | 1·03500 | 60·314 | 9·672 |
| 195 | 1·03700 | 60·198 | 9·654 |
| 200 | 1·03889 | 60·081 | 9·635 |
| 205 | 1·0414 | 59·93 | 9·611 |
| 210 | 1·0434 | 59·82 | 9·594 |
| 212 | 1·0466 | 59·64 | 9·565 |
| 250 | 1·06243 | 58·75 | 9·422 |
| 300 | 1·09563 | 56·97 | 9·136 |
| 400 | 1·15056 | 54·25 | 8·700 |
| 500 | 1·22005 | 51·16 | 8·204 |

## Expansion of Gases.

The volume of atmospheric air is increased in the ratio of 1 to 1·365, in rising in temperature from 32° to 212° F., under constant pressure; and when the volume is constant, the pressure is increased in the ratio of 1 to 1·3665.

The expansion under constant pressure is uniform, and is at the rate of $\frac{1}{493\cdot2}$ part of the volume at 32° F., for each degree of rise of temperature: say the fraction $\frac{1}{493}$. At this rate of

contraction the absolute zero of the Fahrenheit scale, or point of no heat, is $(493-32=)-461°$ F., or 461° below 0° on the scale. On the Centigrade scale, the absolute zero is —274°. The absolute temperature by the Fahrenheit scale is found by adding 461 to the temperature indicated on the thermometrical scale. For a given volume of air or other gases at a given temperature, the volume for any other temperature under a constant pressure is,—

$$V' = V\frac{t'+461}{t+461} \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

When the initial temperature is 62° F., the formula becomes

$$V' = V\frac{t'+461}{523} \quad . \quad . \quad . \quad . \quad . \quad . \quad (10)$$

When the temperature is constant, the volume varies as the pressure, or

$$V' = V\frac{p}{p'} \quad . \quad . \quad . \quad . \quad . \quad . \quad (11)$$

When the temperature and pressure change,—

$$V' = V\frac{p(t'+461)}{p'(t+461)} \quad . \quad . \quad . \quad . \quad . \quad (12)$$

When the initial temperature is 62° F., and the initial pressure is 14·7 lbs. per square inch, the formula becomes

$$p' = \frac{V(t'+461)}{35{\cdot}58V'} \quad . \quad . \quad . \quad . \quad . \quad . \quad (13)$$

When in addition the volume is constant, this formula becomes

$$p' = \frac{t'+461}{35{\cdot}58} \quad . \quad . \quad . \quad . \quad . \quad . \quad (14)$$

The product of the volume and pressure of a constant weight of a gas varies as the absolute temperature.

$$\text{(1 pound of air) } Vp = \frac{(t+461)}{2{\cdot}7074} \quad . \quad . \quad . \quad . \quad . \quad . \quad (15)$$

And the volume of one pound of air at any pressure and any temperature, is

$$V = \frac{(t+461)}{2{\cdot}7074p} \quad . \quad . \quad . \quad . \quad . \quad . \quad (16)$$

$V$ = initial volume of gas.
$V'$ = final volume of gas.
$t$ = initial temperature.
$t'$ = final temperature.
initial pressure.
nal pressure.

## Specific Heat.

The specific heat of a body is its capacity for heat relative to that of water as a standard; of which the specific heat is that required to raise the temperature of 1 pound of water at 32° F., one degree Fahrenheit: in short, the British unit of heat. The specific heat of water is not constant; but increases slightly with the temperature, in so much that the heat required to raise the temperature from 32° to 212° F., through 180 degrees, is 180·9 units; and the average specific heat is 1·005, or one-half per cent. more than that at 32° F.

The specific heat of all solids and liquids is variable, gradually augmenting with the temperature. For temperatures under 212°, they are nearly constant.

The specific heat of perfect gases is constant.

TABLE 256.—SPECIFIC HEAT OF METALS.

| | | | |
|---|---|---|---|
| Antimony | ·0507 | Manganese | ·1441 |
| Bismuth | ·0308 | Mercury, solid | ·0319 |
| Brass | ·0939 | „ liquid | ·0333 |
| Copper | ·0951 | Nickel | ·1086 |
| Cymbal metal | ·086 | Platinum, sheet | ·0324 |
| Gold | ·0324 | „ spongy | ·0329 |
| Iridium | ·1887 | Silver | ·0570 |
| Iron, cast | ·1298 | Steel | ·1165 |
| „ wrought | ·1138 | Tin | ·0569 |
| Lead | ·0314 | Zinc | ·0955 |

TABLE 257.—SPECIFIC HEAT OF OTHER MINERAL SUBSTANCES.

| | | | |
|---|---|---|---|
| STONES. | | CARBONACEOUS—*con.* | |
| Brickwork and masonry | ·20 | Graphite, natural | ·2019 |
| Marble | ·2129 | „ of blast furnaces | ·497 |
| Chalk | ·2148 | | |
| Quicklime | ·2169 | SUNDRY. | |
| Magnesian limestone | ·2174 | Glass | ·1977 |
| CARBONACEOUS. | | Ice | ·504 |
| | | Phosphorus | ·2503 |
| Coal | ·2411 | Soda | ·2311 |
| Charcoal | ·2415 | Sulphate of lead | ·0872 |
| Cannel coke | ·2031 | „ lime | ·1966 |
| Coke of pit coal | ·2008 | Sulphur | ·2026 |
| Anthracite | ·2017 | | |

TABLE 258.—SPECIFIC HEAT OF LIQUIDS.

| | | | |
|---|---|---|---|
| Alcohol | ·6588 | Turpentine | ·4160 |
| Benzine | ·3932 | Vinegar | ·9200 |
| Mercury | ·0333 | Water, at 32° F. | 1·0000 |
| Olive oil | ·3096 | „ 212° F. | 1·0130 |
| Sulphuric acid :— | | „ 32° to 212° F. | 1·0050 |
| Density, 1·87 | ·3346 | Wood spirit | ·6009 |
| „ 1·30 | ·6614 | | |

TABLE 259.—SPECIFIC HEAT OF GASES.

| For Equal Weights. | At Constant Pressure. | At Constant Volume. |
|---|---|---|
| Air | ·2377 | ·1688 |
| Carbonic acid ($CO_2$) | ·2164 | ·1714 |
| „ oxide (CO) | ·2479 | ·1768 |
| Hydrogen | 3·4046 | 2·4096 |
| Light carburetted hydrogen | ·5929 | ·4683 |
| Nitrogen | ·2440 | ·1740 |
| Oxygen | ·2182 | ·1559 |
| Steam, saturated | ... | ·3050 |
| Steam gas | ·4750 | ·3700 |
| Sulphurous acid | ·1553 | ·1246 |

TABLE 260.—SPECIFIC HEAT OF WATER AT VARIOUS TEMPERATURES.

| Temperature. | Specific Heat. | Heat to raise 1lb. of Water from 32° F. to given Temperature. | Temperature. | Specific Heat. | Heat to raise 1lb. of Water from 32° F. to given Temperature. |
|---|---|---|---|---|---|
| ° Fahr. | | Units. | ° Fahr. | | Units. |
| 32 | 1·0000 | 0·000 | 248 | 1·0177 | 217·449 |
| 50 | 1·0005 | 18·004 | 266 | 1·0204 | 235·791 |
| 68 | 1·0012 | 36·018 | 284 | 1·0232 | 254·187 |
| 86 | 1·0020 | 54·047 | 302 | 1·0262 | 272·628 |
| 104 | 1·0030 | 72·090 | 320 | 1·0294 | 291·132 |
| 122 | 1·0042 | 90·157 | 338 | 1·0328 | 309·690 |
| 140 | 1·0056 | 108·247 | 356 | 1·0364 | 328·320 |
| 158 | 1·0072 | 126·378 | 374 | 1·0401 | 347·004 |
| 176 | 1·0089 | 144·508 | 392 | 1·0440 | 365·760 |
| 194 | 1·0109 | 162·686 | 410 | 1·0481 | 384·588 |
| 212 | 1·0130 | 180·900 | 428 | 1·0524 | 403·488 |
| 230 | 1·0153 | 199·152 | 446 | 1·0568 | 422·478 |

TABLE 261.—SPECIFIC HEAT OF WOODS.

| | | | |
|---|---|---|---|
| Turpentine | ·467 | Oak | ·570 |
| Pear tree | ·500 | Fir | ·650 |

TABLE 262.—VOLUME OF 1 POUND OF AIR AT ATMOSPHERIC PRESSURE, 14·7 LBS. PER SQUARE INCH.

| Temperature. | Volume of One Pound. | Temperature. | Volume of One Pound. | Temperature. | Volume of One Pound. |
|---|---|---|---|---|---|
| ° Fahr. | Cubic Feet. | ° Fahr. | Cubic Feet. | ° Fahr. | Cubic Feet. |
| 0 | 11·583 | 230 | 17·362 | 525 | 24·775 |
| 32 | 12·387 | 240 | 17·612 | 550 | 25·403 |
| 40 | 12·586 | 250 | 17·865 | 575 | 26·031 |
| 50 | 12·840 | 260 | 18·116 | 600 | 26·659 |
| 62 | 13·141 | 270 | 18·367 | 650 | 27·915 |
| 70 | 13·342 | 280 | 18·621 | 700 | 29·172 |
| 80 | 13·593 | 290 | 18·870 | 750 | 30·428 |
| 90 | 13·845 | 300 | 19·121 | 800 | 31·685 |
| 100 | 14·096 | 320 | 19·624 | 850 | 32·941 |
| 120 | 14·592 | 340 | 20·126 | 900 | 34·197 |
| 140 | 15·100 | 360 | 20·630 | 950 | 35·453 |
| 160 | 15·603 | 380 | 21·131 | 1000 | 36·710 |
| 180 | 16·105 | 400 | 21·634 | 1250 | 42·990 |
| 200 | 16·605 | 425 | 22·262 | 1500 | 49·274 |
| 210 | 16·860 | 450 | 22·890 | 2000 | 61·836 |
| 212 | 16·910 | 475 | 23·518 | 2500 | 74·400 |
| 220 | 17·111 | 500 | 24·146 | 3000 | 86·962 |

TABLE 263.—MELTING POINTS OF ALLOYS OF LEAD, TIN, AND BISMUTH.

| | ° Fahr. | | ° Fahr. |
|---|---|---|---|
| 1 tin, 5 lead | 511 | 6 tin, 1 lead | 381 |
| 1 ,, 3 ,, | 482 | 4 ,, 4 ,, 1 bismuth | 320 |
| 1 ,, 2 ,, | 441 | 2 ,, 2 ,, 1 ,, | 292 |
| 1 ,, 1 ,, | 370 | 1 ,, 1 ,, 1 ,, | 254 |
| 2 ,, 1 ,, | 340 | 5 ,, 3 ,, 8 ,, | 202 |
| 4 ,, 1 ,, | 365 | | |

| Fusible Plugs. | Soften at | Melt at |
|---|---|---|
| | ° Fahr. | ° Fahr. |
| 2 tin, 2 lead | 365 | 372 |
| 2 ,, 6 ,, | 372 | 383 |
| 2 ,, 7 ,, | 377½ | 388 |
| 2 ,, 8 ,, | 395½ | 408 |

TABLE 264.—MELTING POINTS OF METALS.

| | ° Fahr. | | ° Fahr. |
|---|---|---|---|
| Aluminium . . | Full red heat | Iron, cast, white . | 1922 to 2012 |
| Antimony . . . | 1150 | „ wrought . . | 2912 |
| Bismuth . . . | 507 | Lead . . . . | 617 |
| Bronze . . . | 1690 | Mercury . . . . | —39 |
| Copper . . . | 1996 | Silver . . . . | 1873 |
| Gold, standard . . | 2156 | Steel . . . . | 2372 to 2552 |
| „ pure . . | 2282 | Tin . . . . . | 442 |
| Iron, cast, gray . . | 2012 | Zinc . . . . . | 773 |

TABLE 265.—MELTING POINTS OF SUNDRY SOLIDS.

| | ° Fahr. | | ° Fahr. |
|---|---|---|---|
| Carbonic acid . . | —108 | Spermaceti . . | 120 |
| Ice . . . . . | 32 | Sulphur . . . | 239 |
| Nitro-glycerine . | 45 | Tallow . . . | 92 |
| Phosphorus . . | 112 | Turpentine . . | 14 |
| Stearine . . . | 109 to 120 | Wax, rough . . | 142 |
| | | „ bleached . | 154 |

TABLE 266.—BOILING POINTS OF LIQUIDS, AND HEAT OF EVAPORATION.

| Liquid. | Boiling Point. | Latent Heat of Evaporation of One Pound. | Total Heat from 32° F. of One Pound. |
|---|---|---|---|
| | ° Fahr. | Units. | Units. |
| Alcohol . . . . . | 173 | 374 | 461·7 |
| Ammonia . . . . . | 140 | ... | ... |
| Benzine . . . . . | 176 | ... | ... |
| Linseed oil . . . . . | 597 | ... | ... |
| Mercury . . . . . | 648 | ... | ... |
| Sulphuric ether . . . . | 100 | 175 | 210·4 |
| Turpentine. . . . . | 315 | 124 | 256·6 |
| Water . . . . . . | 212 | 965·2 | 1146·1 |
| „ sea . . . . . | 213·2 | ... | ... |
| „ saturated brine . . | 226 | ... | ... |
| Wood spirit . . . . | 150 | 475 | 545·9 |

TABLE 267.—HEAT CONDUCTING POWER OF METALS. SILVER = 1000.

(F. Crace-Calvert & R. Johnson.)

| METALS. | Relative Conducting Power. Silver = 1000. |
|---|---|
| Silver | 1000 |
| Gold | 981 |
| Gold, with 1 per cent. of silver | 840 |
| Copper, rolled | 845 |
| Copper, cast | 811 |
| Mercury | 677 |
| Mercury, with 1·25 per cent. of tin | 412 |
| Aluminium | 665 |
| Zinc, rolled | 641 |
| Zinc, cast vertically | 628 |
| Zinc, cast horizontally | 608 |
| Cadmium | 577 |
| Wrought iron | 436 |
| Tin | 422 |
| Steel | 397 |
| Platinum | 380 |
| Sodium | 365 |
| Cast iron | 359 |
| Lead | 287 |
| Antimony, cast horizontally | 215 |
| Antimony, cast vertically | 192 |
| Bismuth | 61 |
| *Influence of a non-metallic substance in combination on the conducting power of a metal.* | |
| Influence of carbon on iron :— | |
| Wrought iron | 436 |
| Steel | 397 |
| Cast iron | 359 |
| Influence of arsenic on copper :— | |
| Cast copper | 811 |
| Copper with 1 per cent. of arsenic | 570 |
| " ·5 " " | 669 |
| " ·25 " " | 771 |

TABLE 268.—FRIGORIFIC MIXTURES.
(Selection.)

| Mixture. | | Fall of Temperature. | Degrees of Cold Produced. |
|---|---|---|---|
| | | Fahr. | Fahr. |
| Nitrate of ammonia | 1 | From + 50° to + 4° | 46° |
| Water | 1 | | |
| Phosphate of soda | 9 | From + 50° to — 21° | 71° |
| Nitrate of ammonia | 6 | | |
| Dilute nitric acid | 4 | | |
| Muriate of soda (common salt) | 1 | From any temperature to — 5° | ... |
| Snow, or pounded ice | 2 | | |
| Muriate of soda | 5 | From any temperature to — 25° | ... |
| Nitrate of ammonia | 5 | | |
| Snow, or pounded ice | 12 | | |
| Dilute sulphuric acid | 2 | From + 32° to — 23° | 55° |
| Snow | 3 | | |
| Potash | 4 | From + 32° to — 51° | 83° |
| Snow | 3 | | |
| Muriate of lime | | From + 20° to — 48° | 68° |
| Snow | | | |

**Conduction of Heat by Metals, Alloys, and Amalgams.**

Messrs. F. Crace-Calvert and R. Johnson investigated the conducting powers of metals, alloys, and amalgams. Of the solid metals square bars 1 centimetre square (·39 inch), and 6 centimetres long (2·36 inches), were employed. Mercury and sodium were deposited in a box of the given dimensions to hold them. The metals and alloys were of pure metals, excepting platinum, aluminium, iron, and sodium, which were only commercially pure. Tables 264 and 266 give the results of the trials. The alloys of tin and lead, and tin and zinc, there is reason to believe, are only mixtures. The alloys of copper and tin appear to be definite chemical compounds, the observed conducting powers being widely different from the powers calculated from those of the elements. In one instance, an alloy of 68 per cent. of copper and 32 per cent. of tin has less than one-fourth of the calculated power. The low conducting powers of the commercial alloys, No. 7, are due to impurities.

Mercury, when so situated that circulation is prevented, is the worst heat-conducting metal known. The conducting

power of silver, the best conductor, being 1000, that of mercury is only 54 when the column is vertical, and the source of heat is applied at the upper part of the column. When the column is horizontal, the power is 679. Water, like mercury, presents a complete barrier to conduction of heat applied at the upper end of a vertical column.

TABLE 269.—HEAT-CONDUCTING POWER OF ALLOYS AND AMALGAMS: SILVER = 1000.

(F. Crace-Calvert & R. Johnson.)

*I. Alloys by which Heat is Conducted in the Ratio of the Calculated Mean Conducting Power of the Metals composing them.*

| ALLOY. | Proportions per Cent., by Weight. | | Actual Relative Conducting Power. Silver = 1000. | Calculated Conducting Power. |
|---|---|---|---|---|
| 1. *Tin and Lead.* | | | | |
| $PbSn^5$ . . . | T | 73·97 | 385 | 386 |
| | L | 26·03 | | |
| PbSn . . . . | T | 36·22 | 239 | 236 |
| | L | 63·78 | | |
| $SnPb^5$ . . . | T | 10·20 | 299 | 301 |
| | L | 89·80 | | |
| 2. *Tin and Zinc.* | | | | |
| $Zn^5Sn$ . . . . | Z | 73·43 | 541 | 572 |
| | T | 26·57 | | |
| ZnSn . . . | Z | 35·61 | 501 | 495 |
| | T | 64·39 | | |
| $ZnSn^5$ . . . . | Z | 9·95 | 456 | 442 |
| | T | 90·05 | | |
| *II. Alloys containing an Excess of the Worse-Conducting Metal.* | | | | |
| 3. *Lead and Antimony.* | | | | |
| PbSb . . . | L | 61·61 | 190 | 251 |
| | A | 38·39 | | |
| $PbSb^5$ . . . . | L | 24·30 | 179 | 215 |
| | A | 75·70 | | |

TABLE 269.—HEAT-CONDUCTING POWER OF ALLOYS (*cont.*).

| Alloy. | Proportions per Cent., by Weight. | | Actual Relative Conducting Power. Silver = 1000. | Calculated Conducting Power. |
|---|---|---|---|---|
| 4. *Antimony and Bismuth.* | | | | |
| Sb Bi . . . | A | 37·74 | 62 | 110 |
| | B | 62·26 | | |
| $Sb\ Bi^5$ . . . | A | 10·82 | 48 | 75 |
| | B | 89·18 | | |
| 5. *Copper and Tin.* | | | | |
| Cu Sn . . . | C | 34·98 | 415 | 558 |
| | T | 65·02 | | |
| $Cu\ Sn^2$ . . . | C | 21·21 | 431 | 504 |
| | T | 78·79 | | |
| $Cu\ Sn^3$ . . . | C | 15·21 | 423 | 481 |
| | T | 84·79 | | |
| $Cu\ Sn^4$ . . . | C | 11·86 | 405 | 468 |
| | T | 88·14 | | |
| $Cu\ Sn^5$ . . . | C | 9·73 | 396 | 459 |
| | T | 90·27 | | |
| The following have excess of copper :— | | | | |
| $Sn\ Cu^3$ . . . | T | 38·21 | 494 | 670 |
| | C | 61·79 | | |
| $Sn\ Cu^4$ . . . | T | 31·73 | 155 | 686 |
| | C | 68·27 | | |
| $Sn\ Cu^5$ . . . | T | 27·10 | 207 | 705 |
| | C | 72·90 | | |
| 6. *Zinc and Copper.* | | | | |
| Cu Zn . . . | C | 49·32 | 688 | 718 |
| | Z | 50·68 | | |
| $Cu\ Zn^2$ . . . | C | 32·74 | 428 | 687 |
| | Z | 67·26 | | |
| $Cu\ Zn^3$ . . . | C | 24·64 | 531 | 672 |
| | Z | 75·36 | | |
| $Cu\ Zn^4$ . . . | C | 19·57 | 589 | 663 |
| | Z | 80·43 | | |
| $Cu\ Zn^5$ . . . | C | 16·30 | 595 | 657 |
| | Z | 83·70 | | |

TABLE 269.—HEAT-CONDUCTING POWER OF ALLOYS (*cont.*).

| ALLOY. | Proportions per Cent., by Weight. | Actual Relative Conducting Power. Silver = 1000. | Calculated Conducting Power. |
|---|---|---|---|
| 6. *Zinc and Copper (continued).* The following have excess of copper :— | | | |
| Zn $Cu^2$ . . . | Z 33·94<br>C 66·06 | 621 | 748 |
| Zn $Cu^3$ . . | Z 25·52<br>C 74·48 | 638 | 764 |
| Zn $Cu^4$ . . . | Z 20·44<br>C 79·56 | 665 | 770 |
| Zn $Cu^5$ . . | Z 17·05<br>C 82·95 | 715 | 780 |
| 7. *Commercial Alloys.* | | | |
| "Yellow brass" | Copper 64·0<br>Zinc 56·0 | 558 | 712 |
| "Pumps and pipes" . . | Copper 80<br>Tin 5<br>Zinc 7·5<br>Lead 7·5 | 426 | 707 |
| "Mud plugs" . | Copper 80<br>Tin 10<br>Zinc 10 | 394 | 754 |
| "Large bearings" . . | Copper 84·05<br>Tin 12·82<br>Zinc 5·13 | 345 | 751 |
| *III. Amalgams (Compounds of Mercury), Solid and Semi-Solid, in which there is an Excess of the Amalgamated Metal.* | | | |
| 8. *Amalgams of Tin.* | | | |
| Hg $Sn^2$ . . | M 45·88<br>T 54·12 | 8·65 | 8·11 |
| Hg $Sn^3$ . . . | M 36·18<br>T 63·82 | 9·45 | 9·2 |
| Hg $Sn^4$ . . | M 29·84<br>T 70·16 | 9·65 | 9·95 |
| Hg $Sn^5$ . . . | M 25·38<br>T 74·62 | 10·6 | 10·5 |

TABLE 269.—HEAT-CONDUCTING POWER OF ALLOYS (*cont.*).

| ALLOY. | Proportions per Cent., by Weight. | Actual Relative Conducting Power. Silver = 1000. | Calculated Conducting Power. |
|---|---|---|---|
| 9. *Amalgams of Zinc.* | | | |
| $HgZn^2$ . . | M 60·63; Z 39·37 | 9·7 | 8·97 |
| $HgZn^3$ . . . | M 54·70; Z 45·30 | 10·45 | 10·05 |
| $HgZn^4$ . . | M 43·50; Z 56·50 | 11·00 | 12·08 |
| $HgZn^5$ . . . | M 38·11; Z 61·89 | 13·95 | 13·05 |
| 10. *Amalgams of Bismuth.* | | | |
| $HgBi^2$ . . | M 31·82; B 68·18 | 2·15 | 1·87 |
| $HgBi^3$ . . . | M 23·86; B 76·14 | 2·6 | 1·89 |
| $HgBi^4$ . . | M 19·03; B 80·97 | 2·55 | 1·90 |
| $HgBi^5$ . . . | M 15·82; B 84·18 | 2·35 | 1·91 |

## COMBUSTION.—FUELS.

### Combustion.

The volume of air consumed chemically in the combustion of fuel is expressed by the formula :—

$$A = 1{\cdot}52\,(C + 3H - {\cdot}4O) \quad . \quad . \quad . \quad (1)$$

A = volume of air as at 62° F., and under one atmosphere of pressure, in cubic feet, per pound of fuel.
A′ = weight of air as at 62° F., per pound of fuel.
C = percentage of constituent carbon.
H = percentage of constituent hydrogen.
O = percentage of constituent oxygen.

The weight of the air thus found by volume is equal to the volume divided by 13·14. Or it is found directly by the formula:—

$$A' = \cdot 116\,(C + 3H - \cdot 4O) \quad . \quad . \quad . \qquad (2)$$

In these formulas the heat evolved by the combustion of the sulphur constituent is not noticed, as it is trifling in proportion.

The volume of the volatile or gaseous products of the complete combustion of one pound of a fuel, as at 62° F., at atmospheric pressure, is, by formula,—

$$V = 1\cdot 52C + 5\cdot 52H \quad . \quad . \quad . \qquad (3)$$

The weight of the gaseous products is, by formula,—

$$w = \cdot 126C + \cdot 358H \quad . \quad . \quad . \qquad (4)$$

$V$ = volume of gaseous products, in cubic feet.
$w$ = weight of gaseous products, in pounds.
$C$ = percentage of constituent carbon.
$H$ = percentage of constituent hydrogen.

The volume at any other temperature is found by the formula for expansion of volume of gases, p. 474.

The proportion of free or unconsumed air usually present in the gaseous products is determined by multiplying the percentage of oxygen, found by analysis, by 4·35. The product is the percentage of free air in parts of the whole mixture.

The heat generated by combustion is as follows:—

| | |
|---|---|
| Carbon . . . . . | 14,500 heat-units per pound. |
| Hydrogen . . . . . | 62,000 ,, |
| Sulphur . . . . . | 4,000 ,, |

The heating power of fuels containing carbon and hydrogen is approximately expressed by the formula:

$$h = 145\,(C + 4\cdot 28H) \quad . \quad . \quad . \quad . \qquad (5)$$

in which $h$ is the total heat of combustion.

The evaporative efficiency for one pound of fuel is

$$e = \cdot 15\,(C + 4\cdot 28H) \quad . \quad . \quad . \quad . \qquad (6)$$

$$\text{or, } e = \frac{h}{966} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (7)$$

$e$ = weight of water evaporable from and at 212°, in pounds, per pound of fuel.

The maximum temperature of combustion of carbon is about 5000° F.; and that of hydrogen is about 5800° F.

### Fuels.

*Coal* consists mainly of carbon, which varies from 50 per cent. to 80 per cent., by weight, of the fuel. Lignite or brown coal contains from 56 to 76 per cent. of carbon. The average composition of British coal is, say, 80 per cent. of carbon, 5 per cent. of hydrogen, 1¼ per cent. of sulphur, 1⅕ per cent. of nitrogen, 8 per cent. of oxygen, and 4 per cent. of ash. The fixed carbon or coke averages 61 per cent. The average specific gravity is 1·279 ; average weight of a solid cubic foot, 80 pounds ; and of a cubic foot heaped, 50 pounds ; average bulk of one ton heaped, 44½ cubic feet ; equivalent evaporative efficiency, 15·40 pounds of water per pound of coal, from and at 212° F.

Bituminous coals hold from 6 per cent. to 10 per cent. of water hygroscopically ; Welsh coals from ⅝ per cent. to 2¾ per cent.

*Coke* contains from 85 to 97½ per cent. of carbon ; from ¾ to 2 per cent. of sulphur, and from 1½ to 14½ per cent. of ash. The average composition may be taken as 93½ per cent. of carbon, 1¼ per cent. of sulphur ; 5½ per cent. of ash. It weighs from 40lbs. to 50lbs per cubic foot solid, and about 30lbs. broken and heaped. The volume of 1 ton heaped is from 70 to 80 cubic feet ; average, 75 cubic feet. Coke is capable of absorbing from 15 to 20 per cent. of moisture. There is ordinarily from 5 per cent. to 10 per cent. of hygrometric moisture in coke.

*Lignite* or *brown coal* consists chiefly of carbon, oxygen, and nitrogen ; averaging in perfect lignite, 69 per cent. of carbon, 5 per cent. of hydrogen, 20 per cent. of oxygen and nitrogen, and 6 per cent. of ash. The weight is about 80 pounds per cubic foot. Imperfect lignite weighs about 72 pounds per cubic foot.

*Asphalte* consists, in round numbers, of 79 per cent. of carbon, 9 per cent. of hydrogen, 9 per cent. of oxygen and nitrogen, and 3 per cent. of ash. It weighs about 66 pounds per cubic foot.

*Woods* of various kinds are approximately the same in composition, averaging, when perfectly dry, 50 per cent. of carbon, 6 per cent. of hydrogen, 41 per cent. of oxygen, 1 per cent. of nitrogen, and 2 per cent. of ash. Green wood when cut down contains moisture to the extent of 45 per cent. of its weight. Wood kept in a dry place holds from 15 per cent. to 20 per cent. of water. In a closely packed pile of wood, consisting of uncloven stems, the interstitial space is about 30 per cent. of the gross bulk. A cord of pine-wood, in the United States of America, is 4 feet by 4 feet by 8 feet, and has a volume of

128 cubic feet. Its weight averages 2,700 pounds, or 21 pounds per cubic foot. A "corde" of wood, in France, has a volume of 4 cubic feet metrés or 141 cubic feet. Ordinarily dry wood, in France, averages 20 pounds weight per cubic foot heaped, or 114 cubic feet per ton heaped.

*Wood charcoal*, as manufactured in the forests, consists of 79 per cent. of carbon, 2 per cent. of free hydrogen, 11 per cent. of hydrogen, oxygen, and nitrogen, and 8 per cent. of ash:—average composition. The yield of charcoal varies from 17 to 21 per cent. in weight of the wood, which is a mixture of oak, beech, poplar, willow, and elm. The weight of charcoal as manufactured, heaped, is 14 pounds per cubic foot; in small pieces, heaped, 25 pounds per cubic foot. The bulk of 1 ton heaped is 160 cubic feet and 88·5 cubic feet respectively. Charcoal holds generally 10 or 12 per cent. of moisture.

*Peat*, cut and dried, has a specific gravity varying from ·22 to 1·06. Ordinary air-dried peat holds from 20 per cent. to 30 per cent. of its gross weight of moisture. Perfectly dry peat contains. on an average, 59 per cent. of carbon, 6 per cent. of hydrogen, 30 per cent. of oxygen, 1¼ per cent. of nitrogen, and 4 per cent. of ash. The weight of one cubic foot, heaped or stalked, is from 6 pounds to 22½ pounds per cubic foot; or the volume of one ton is from 370 cubic feet to 100 cubic feet. Condensed peat, such as is macerated and mixed, weighs from 44 to 57 pounds per cubic foot stalked, or the volume is from 51 to 40 cubic feet per ton.

*Peat charcoal* is yielded at the rate of from 30 per cent. to 40 per cent. by weight of good peat. It contains from 85 to 90 per cent. of carbon, and from 10 to 15 per cent. of ash.

*Straw*, in its ordinary state, consists of about 16 per cent. of water, 36 per cent. of carbon, 5 per cent. of hydrogen, 38 per cent. of oxygen, ½ per cent. of nitrogen, and 4½ per cent. of ash. Pressed straw weighs from 6 pounds to 8 pounds per cubic foot.

*Petroleum* consists of about 85 per cent. of carbon, 13 per cent. of hydrogen, and 2 per cent. of oxygen; having ·87 specific gravity, and weighing 8·70 pounds per gallon. *Petroleum oils* consist of about 73 per cent. of carbon, and 27 per cent. of hydrogen; having ·71 specific gravity, and weighing 7·10 pounds per gallon.

*Coal Gas*, which will be noticed in detail, consists, in round numbers, of 12 per cent. of olefiant gas, 53 per cent. of marsh gas, 14 per cent. of carbonic oxide, 8 per cent. of hydrogen, 6 per cent. of nitrogen, and a small fraction of oxygen.

For the above-named fuels, the Heat of Combustion is recorded in Table 267, with the quantity of air chemically consumed.

TABLE 270.—HEAT OF COMBUSTION OF FUELS.

| Fuel. | Air Chemically Consumed per Pound of Fuel. | | Total Heat of Combustion of One Pound of Fuel. | Equivalent Evaporative Power, from and at 212° F., Water per Pound of Fuel. |
|---|---|---|---|---|
| | Pounds. | Cub. Ft. at 62° F. | Units. | Pounds. |
| Coal of average composition | 10·7 | 140 | 14,700 | 15·22 |
| Coke | 10·81 | 142 | 13,548 | 14·02 |
| Lignite | 8·85 | 116 | 13,108 | 13·57 |
| Asphalte | 11·85 | 156 | 17,040 | 17·64 |
| Wood, desiccated | 6·09 | 80 | 10,974 | 11·36 |
| Wood, 25 per cent. moisture | 4·57 | 60 | 7,951 | 8·20 |
| Wood charcoal, desiccated | 9·51 | 125 | 13,006 | 13·46 |
| Peat, desiccated | 7·52 | 99 | 12,279 | 12·71 |
| Peat, 30 per cent. moisture | 5·24 | 69 | 8,260 | 9·53 |
| Peat charcoal, desiccated | 9·9 | 130 | 12,325 | 12·76 |
| Straw | 4·26 | 56 | 8,144 | 8·43 |
| Petroleum | 14·33 | 188 | 20,411 | 21·13 |
| Petroleum oils | 17·93 | 235 | 27,531 | 28·50 |
| Coal gas, per cubic foot at 62° F. | ... | ... | 630 | ·70 |

## WARMING AND VENTILATION.—COOKING-STOVES.

### Warming and Ventilation.

The quantity of air required for ventilation of buildings is variously estimated at from 3½ cubic feet to 20 cubic feet per minute, or from 210 to 1,200 cubic feet per hour per head of inmates in ordinary good health. In public schools, 1,800 cubic feet per hour per head is recommended; for

theatres and concert-halls, from 1,500 to 3,000 cubic feet; for hospitals, from 4,000 to 6,000 cubic feet. For each lamp or gas-burner employed, from 30 to 60 cubic feet per hour should be provided.

In warming dwelling-rooms by open coal fires and by close stoves, the results of the tests made by Mr. D. K. Clark for the Smoke Abatement Committee, showed that the heat of combustion was distributed as follows:—

| | Open Grates. | Close Stoves. |
|---|---|---|
| Heat carried up the chimney | 43 | 24 |
| Radiated and conducted heat absorbed by the walls | 42 | 54 |
| Heat lost by radiation and conduction externally, and heat lost by imperfection of combustion | 15 | 22 |
| | 100 | 100 |

The grates and stoves were tested in rooms 15 feet square, 17 feet total height; having 3,600 cubic feet of capacity.

| | Open Grates. | Close Stoves. |
|---|---|---|
| Average weight of Wallsend coal consumed per hour | 3·65 lbs. | 3·87 lbs. |
| Average rise of temperature maintained in the room | 10·83° F. | 17·74° F. |
| Average rise of temperature maintained per lb. of coal consumed per hour | 3·22° F. | 4·48° F. |

It was shown that, of the open grates, those constructed on the principle of drawing the combustible gases through the incandescent fuel, were the most efficient; and that, of these, the best were those in which the fresh fuel was supplied below the fire, the combustible gases rising upwards through it. Ordinary open fires, having either bottom grids or solid floors, were the least effective for warming relatively to the quantity of coal consumed per hour.

The efficiency generally varied inversely as the depth of the smoke-shade at the top of the chimney.

The velocity and temperature of draught in the chimney, which was 8¾ inches in diameter, were as follows:—

| | Open Grates. | Close Stoves. |
|---|---|---|
| Velocity of draught in feet per minute | 376 ft. | 275 ft. |

| | Open Grates. | Close Stoves. |
|---|---|---|
| Temperature in chimney . . | 197° F. | 200° F. |
| Actual volume of gases passed up the chimney in cubic feet per hour . . . . . . | 9,400 ft. | 6,880 ft. |
| Equivalent volume, as for 62° F. in cubic feet . . . . . | 7,471 " | 5,443 " |
| Equivalent volume, per lb. of coal, in cubic feet . . . . | 2,099 " | 1,158 " |
| Percentage volume of burnt gases in chimney . . . . | 7 per cent. | 12½ per cent. |
| Percentage volume of atmospheric air in chimney . . . . | 93 " | 87½ " |

## Heating by Steam ("Steam").

In heating buildings by steam, the boiler power and pipe surface depend much upon the kind of building and the situation. If heating be done by indirect radiation, from 50 to 100 per cent. more heat is required than for direct radiation.

RULE.—*For direct radiating surface.* Add together the area of glass in the windows in square feet, the volume of air in cubic feet required to be changed per minute, and one-twentieth of the surface of external wall and roof. Multiply the sum by the difference between the required temperature of the room and the minimum temperature of the external air; divide the product by the difference between the temperature of the steam in the pipes and the required temperature of the room. The quotient is the required radiating surface in square feet.

Each square foot of radiating surface gives off, in average practice, three heat-units per hour for each degree of difference of temperature between the steam inside and the air outside; varying 50 per cent. more or less.

In *indirect heating*, the efficiency of the radiating surface increases, and the temperature of the air diminishes, when the quantity of air passed through the coil increases. Thus, one square foot of radiating surface, with steam at 212° F., will heat 100 cubic feet of air per hour from 32° to 150°; or 300 cubic feet from 32° to 100°, in the same time. Small pipes are more effective than large pipes. When the diameter is doubled, 20 per cent. additional surface should be allowed; for three times the diameter, 30 per cent.

One square foot of boiler surface can supply to from 7 to 10 square feet of radiating surface. Each horse-power of boiler,

—measured by the evaporation of 30 pounds of water under 75 lbs. pressure, per hour—will supply to from 240 to 360 feet of 1-inch steam pipe, or from 80 to 120 square feet of radiating surface.

Under ordinary conditions, one horse-power will heat various buildings as follows :—

| | Cubic feet. |
|---|---|
| Brick dwellings, in blocks, as in cities | 15,000 to 20,000 |
| ,, stores | 10,000 to 15,000 |
| ,, dwellings, exposed on all sides | 10,000 to 15,000 |
| ,, mills, shops, factories, &c. | 7,000 to 10,000 |
| Wooden dwellings, exposed | 7,000 to 10,000 |
| Foundries and wooden shops | 6,000 to 10,000 |
| Exhibition buildings, largely of glass | 4,000 to 15,000 |

## Heating Rooms by Hot Water.

Mr. Hood allows one square foot of direct heating surface of boilers, or three square feet of flue-surface for every 40 feet of 4-inch pipe containing hot water for heating buildings; and, allowing about 10 pounds of good coal consumed per hour per square foot of fire-grate, 20 square inches area of grate suffice for heating 40 feet of 4-inch pipe.

Mr. Jones makes the following allowance of fire-grate per 100 feet of 4-inch pipe, for different kinds of boiler :—

| | Grate-area. |
|---|---|
| Plain saddle | 50 square inches. |
| Cheek-end saddle | 45 ,, ,, |
| Chambered saddle | 40 ,, ,, |
| Double-chambered saddle | 35 ,, ,, |
| Trentham vertical cylindrical | 35 ,, ,, |

Mr. Hood gives the following rule for the length of 4-inch pipe required to heat 1,000 cubic feet of air per minute :—

Multiply the volume of air in cubic feet to be warmed per minute, by the difference of the temperature in the room and the external temperature, and by 0·56, and divide the product by the difference of the internal temperature and that of the pipes. The quotient is the length of 4-inch pipe in feet.

The following, in Table 268, are a selection of values calculated by this rule :—

TABLE 271.—LENGTH OF 4-INCH PIPE TO HEAT 1,000 CUBIC FEET OF AIR PER MINUTE.
Temperature of the Pipe. 200° F.

| External Temperature | Temperature of the Room (Fahr.). | | | | | | |
|---|---|---|---|---|---|---|---|
| | 50° | 55° | 60° | 65° | 70° | 75° | 80° |
| ° Fahr. | Feet. | Feet. | Feet. | Feet. | Feet. | Feet. | Feet. |
| 10 | 150 | 174 | 200 | 229 | 259 | 292 | 328 |
| 16 | 127 | 151 | 176 | 204 | 233 | 265 | 300 |
| 20 | 112 | 135 | 160 | 187 | 216 | 247 | 281 |
| 24 | 97 | 120 | 144 | 170 | 199 | 229 | 262 |
| 32 | 67 | 89 | 112 | 137 | 164 | 193 | 225 |
| 40 | 37 | 58 | 80 | 104 | 129 | 157 | 187 |
| 44 | 22 | 42 | 64 | 87 | 112 | 139 | 168 |
| 50 | ... | 19 | 40 | 62 | 86 | 112 | 140 |
| 52 | ... | 11 | 32 | 54 | 77 | 103 | 131 |

Mr. Jones gives the following Table 269, for appproximate engths of 4-inch pipe required for every 1,000 cubic feet. The required lengths may be varied to suit special conditions.

TABLE 272.—LENGTH OF 4-INCH PIPE REQUIRED FOR EVERY 1,000 CUBIC FEET.

| Building. | Temperature Required. | Length of Pipe. |
|---|---|---|
| | ° Fahr. | Feet. |
| Public buildings . . . . . . | 55 | 6 to 7 |
| Workshops, warehouses, &c. . . | 55 | 6 to 7 |
| Schools, churches, offices, bed-rooms, &c. . . . . . . . | 60 | 7 to 8 |
| Shops, waiting rooms, &c. . . . | 60 | 10 to 11 |
| Living rooms . . . . . . . | 65 | 10 to 11 |
| Drying stoves (closed rooms) . . | 100 | 100 |
| " " . . | 110 | 120 |
| " " . . . | 120 | 170 |
| " " . . . | 130 | 240 |
| Conservatories, greenhouses, &c. . | 45 to 50 | 35 |
| Ferneries, &c. . . . . . . . | 50 to 55 | 40 |
| Vineries, stoves . . . . . . . | 55 to 60 | 45 |
| " " . . . . . . . | 60 to 65 | 50 |
| Orchids, stoves . . . . . . . | 65 to 70 | 55 |
| " " . . . . . . . | 70 to 75 | 60 |
| ...eries, forcing houses . . . . | 75 to 80 | 70 |

## Distribution of Heat in Furnaces.

In melting pig-iron in an ordinary cupola by the combustion of 30 per cent. of its weight of coke, Peclet estimated that 14 per cent. only of the heat of combustion was actually utilised.

In an ordinary metallurgical re-heating furnace, one ton of coal is consumed in heating 1¾ tons of wrought-iron to the welding point, 2,700° F.; showing that only 4¼ per cent. of the whole heat generated is appropriated by the metal.

Barely 1½ per cent. of the whole heat generated is absorbed in melting pot steel in ordinary furnaces. In the Siemens regenerative furnace, a ton of steel is melted for the combustion of 12 cwts. of small coal, showing that 6 per cent. of the heat produced is utilised.

Sir I. Lowthian Bell's estimate of the distribution of heat in a blast furnace from Durham coke, which contains 92·5 per cent. of carbon, for the production of 1 ton of pig-iron is as follows :—He assumes that 30·4 per cent. of the carbon of the fuel—Durham coke—which escapes in a gaseous form, is carbonic acid ; and that, therefore, only 51·27 per cent. of the heating power of the fuel is developed, and the remaining 48·73 per cent. leaves the tunnel head undeveloped. He adopts as a unit of heat, the heat required to raise the temperature of 112 pounds of water 1° centigrade. To produce 1 ton of pig-iron there are required 11 cwts. of limestone and 49 cwts. of calcined ironstone. The ironstone consists of 18·6 cwts. of iron, 9 cwts. of oxygen, and 21·4 cwts. of earths.

*For 1 ton of Pig-Iron.*

| | | Units. | Per cent. |
|---|---|---|---|
| Evaporation of water in coke and chemical action in smelting | | 48,354 | 54·1 |
| Fusion of pig-iron | | 6,600 | 7·4 |
| Fusion of slag | | 15,356 | 17·2 |
| Expansion of blast | | 3,700 | 4·1 |
| For direct work of furnace | | 74,010 | 82·8 |
| Loss by radiation through the walls | 3,600 | | |
| Carried away by tuyere water | 1,800 | | |
| Sensible heat of gaseous products | 10,000 | | |
| Waste | | 15,400 | 17·2 |
| Total heat generated in the furnace | | 89,410 | 100·0 |

## Gas-Heating Stoves and Fires.

The results of Mr. D. K. Clark's test-trials of Gas-Heating Stoves and Fires of various classes, are summarised in Table 273.

TABLE 273.—AVERAGE RESULTS OF TEST-TRIALS OF GAS-HEATING STOVES AND FIRES.

| Classes of Stoves. | External Temperature. | Temperature in the Testing Room. | Difference, or Elevation of Temperature. | Gas Consumed per Hour. | Gas per Hour per Degree of Elevation of Temperature. | Room Space per Cubic Foot of Gas per Hour per Degree of Elevation of Temperature. |
|---|---|---|---|---|---|---|
| | ° Fahr. | ° Fahr. | ° Fahr. | Cub. Ft. | Cub. Ft. | Cub. Ft. |
| I. Close stoves . . . | 57·1 | 64·3 | 7·2 | 10·9 | 1·35 | 218 |
| II. Open stoves:— | | | | | | |
| Asbestos fuel stoves . | 57·4 | 72·1 | 14·7 | 28·7 | 2·05 | 175 |
| Tile stoves . . . | 59·7 | 69·2 | 9·5 | 16·9 | 1·84 | 195 |
| III. Gas baskets or gas fires: | | | | | | |
| Reflector stoves . . | 58·7 | 66·5 | 7·8 | 11·1 | 1·55 | 232 |
| Gas fires . . . | 55·8 | 63·7 | 7·9 | 12·2 | 1·57 | 229 |

The volume of the testing-room was about 3,600 cubic feet. The consumption of gas per hour per degree of elevation of temperature is the measure of relative effectiveness: showing that the reflector stoves were the most effective, consuming about 1½ cubic feet of gas per hour per degree. Gas baskets, or gas fires, were practically of equal efficiency with the reflector stoves. Next in order, are close stoves, then tile stoves; and, lastly, asbestos fuel stoves, consuming 2 cubic feet of gas per hour per degree.

The ventilation of the room, as dependent on draught in the chimney, averaged from 6,000 to 10,000 cubic feet of air, as at 62° F., per hour: showing that a volume of air of from twice to thrice the capacity of the room, was passed up the chimney per hour. By the natural draught in the chimney independent of the augmentation of draught by the stove heat, 2,400 cubic feet of air passed up the chimney per hour.

The average efficiency of the stoves was upwards of 90 per cent.; or, less than 10 per cent. of the heat generated was wasted up the chimney.

## Cooking Ranges.

From the average results of tests of Cooking Ranges at the Smoke Abatement Exhibition, it appears that a joint from the sirloin weighing 12½ lbs., and a sample of puff pastry following

the joint, were roasted and baked in two hours, with a consumption of 17 pounds of hard steam coal.

### Cooking with Gas.*

From the average results of numerous test-trials of gas-cooking stoves, having burners inside, in roasting legs of mutton weighing from 8 lbs. to 9 lbs. each, the loss of weight and net weight were as follows :—

*Average distribution of Joints when very well done.*

| | | | |
|---|---|---|---|
| Joint as cooked . . . . . | 6 lbs. 7 ozs. | or | 77 per cent. |
| Dripping . . . . . . . | 1 ,, 0 ,, | ,, | 12 ,, ,, |
| Loss by evaporation . . . . | 0 ,, 15 ,, | ,, | 11 ,, ,, |
| | 8 lbs. 6 ozs. | or | 100 per cent. |

The bone of a leg of mutton weighed 1 pound.

The average temperature in the oven was 378° F. The average length of time roasting was 2 hours 16 minutes ; or at the rate of a quarter of an hour per pound weight of the joint, with 16 minutes for the odd 6 ounces. The average quantity of gas consumed while roasting was 22·6 cubic feet of the average temperature 56° F., or at the rate of 2·70 cubic feet per pound of fresh joint, and of 10 cubic feet per hour. Adding the gas consumed in heating up the stoves, which was an average of 3·40 cubic feet, the sum is 26 cubic feet of gas ; the total average consumption being at the rate of 3·1 cubic feet per pound of the fresh joint. The average capacity of the ovens was 2·54 cubic feet, represented nearly by that of Davis's No. 9 Stove, which is 22 inches high above the burners, and 14½ inches square. The flavour of the meat roasted by plain gas was decidedly better than that of the meat roasted by atmospheric gas.

Externally heated stoves consumed about one-third more gas than internally heated stoves.

The distribution of the heat of combustion of the 22 cubic feet of gas consumed in roasting the joint, averaging for 25 trials, was as follows :—

| | Heat Units. | | Gas.—Cubic Feet at 62° F. | | Per cent. |
|---|---|---|---|---|---|
| Roasting the joint . . . . . | 2,203 | or | 3·54 | or | 16·1 |
| Carried off in the burnt gases . . | 585 | ,, | 0·94 | ,, | 4·3 |
| Dispersed by external radiation and conduction . . . . | 10,896 | ,, | 17·52 | ,, | 79·6 |
| | 13,684 | ,, | 22·0 | ,, | 100·0 |

Showing that barely one-sixth of the whole of the heat generated was utilised in roasting; that the proportion of heat carried off in the burnt gases was comparatively insignificant, and that four-fifths of the total heat was dispersed wastefully.

* See *International Electric and Gas Exhibition*, 1882 83 : *Report on Gas Section*, by D. K. Clark.

## STEAM.

The leading properties of saturated steam are stated in Table 274 (p. 508). The specific heat of saturated steam is ·305 at constant volume. That of steam gas is ·3643 at constant volume, and ·475 at constant pressure.

Steam of from 25 lbs. to 215 lbs. absolute pressure flows into the atmosphere, at a velocity averaging about 900 feet per second, as calculated for constant density,—that is to say, on the assumption that the steam does not expand in the course of the outflow. It actually expands and attains a velocity by expansion averaging 1450 feet per second.

*Equivalent Weight of Steam formed from and at* 212° *F.*—Let $w$ = the weight of water evaporated per pound of a fuel, from water supplied at the temperature $t$, into steam of the total heat H, measured from 32° F. Let $w'$, $t'$, and $H'$, be the corresponding values for steam of any other pressure. Then the total heat expended in evaporating 1 pound of water is $H + 32 - t$, or $H' + 32 - t$; and

$$w' = w \frac{H + 32 - t}{H' + 32 - t'} \quad . \quad . \quad . \quad . \quad (1)$$

Let $H'$ be the total heat of steam generated at 212° F., or 1146 units; and $t' = 212°$ E. By substitution and reduction,

$$w' = w \frac{H + 32 - t}{966} \quad . \quad . \quad . \quad . \quad . \quad (2)$$

in which $w'$ is the equivalent weight of water evaporated from and at 212° F.

RULE.—*To find the equivalent weight of water evaporated from and at* 212° *F., when a given weight of water is supplied at a given temperature, and evaporated under a given pressure.*—Find in Table 271, the total heat of the steam generated at the given absolute pressure; add 32 to it, and from the sum subtract the temperature of the feed-water; divide the remainder by 966, and multiply the quotient by the given weight of water. The product is the equivalent weight of water as evaporated from and at 212° F.

### Moisture or Priming in Steam.

Blow a quantity of the so-called steam into a vessel holding a given weight of cold water: noting the pressure and the

weight of the steam blown in, and the initial and final temperatures of the mixture. An addition is to be made to the initial weight of water, to represent the weight of water equivalent to that of the vessel containing the water, in terms of their respective specific heats. A corresponding addition is to be made for such portion of the apparatus as is immersed in the water.

Let W = weight of condensing water, plus the equivalent weight of the receiver and apparatus immersed in the water.

$w$ = weight of nominal steam discharged into the vessel under water.

W + $w$ = gross weight of mixture of nominal steam and condensing water.

H = total heat of one pound of the steam, reckoned from the temperature of the condensing water.

H$w$ = total heat delivered by the gross weight of nominal steam discharged, taken as dry steam.

$t$ = initial temperature of condensing water.

$t'$ = final do. do. do.

$\kappa$ = augmentation of specific heat of water due to rise of temperature.

L = latent heat of one pound of steam of the given initial pressure.

L$w$ = latent heat of steam discharged into the vessel, taking it as dry steam.

P = weight of priming or moisture in percentage of the gross weight of nominal steam.

$$P = 100 \frac{Hw - [(W + w) \times (t' - t + \kappa)]}{Lw} \quad . \quad . \quad . \quad (3)$$

RULE.—*To determine the proportion of moisture or priming in steam.*—To the rise of temperature add the augmentation of specific heat of the water. Multiply the gross weight of nominal steam and condensing water by this sum, and deduct the product from the constituent or total heat of the weight discharged into the vessel, taken as dry steam; and reckoned from the temperature of the condensing water. Multiply the remainder by 100, and divide by the latent heat of the steam taken as dry. The quotient is the proportion of water in percentage of the gross weight of nominal steam.

If there be no remainder, the steam is taken as dry. If, on the contrary, the product be greater than the constituent heat, the difference is evidence of superheated steam, the percentage quantity of which is found by multiplying it by 100, and dividing by the given constituent heat.

## TABLE 274.—SATURATED STEAM.

| Absolute Pressure per Square Inch. | Temperatures. | Total Latent Heat of Steam from Water supplied at 32° F. | Water-heat of Steam (to raise Temperature of Water from 32° F.). | Total Heat of One Pound of Steam from Water supplied at 32° F. | Density, or Weight of One Cubic Foot of Steam. | Volume of One Pound of Steam. | Relative Volume, or Cubic Feet of Steam from One Cubic Foot of Water. |
|---|---|---|---|---|---|---|---|
| 1. | 2. | 6. | 7. | 3. | 8. | 9. | 10. |
| Lbs. | ° Fahr. | Units. | Units. | Units. | Lbs. | Cub. Ft. | Rel. Vol. |
| 0·5 | 80·2 | 1058·4 | 47·1 | 1105·5 | ·001376 | 726·608 | 45307·5 |
| 1 | 102·1 | 1042·9 | 69·6 | 1112·5 | ·003027 | 330·360 | 20599·1 |
| 1·5 | 115·9 | 1033·2 | 83·5 | 1116·7 | ·004433 | 225·580 | 14066·1 |
| 2 | 126·3 | 1025·8 | 93·9 | 1119·7 | ·005811 | 172·080 | 10730·0 |
| 2·5 | 134·6 | 1019·9 | 102·6 | 1122·5 | ·007169 | 139·488 | 8697·8 |
| 3 | 141·6 | 1015·0 | 109·6 | 1124·6 | ·008511 | 117·500 | 7326·5 |
| 3·5 | 147·7 | 1010·6 | 115·8 | 1126·4 | ·009839 | 101·632 | 6337·3 |
| 4 | 153·1 | 1006·8 | 121·3 | 1128·1 | ·01116 | 89·632 | 5589·0 |
| 4·5 | 157·9 | 1003·4 | 126·2 | 1129·6 | ·01246 | 80·231 | 5002·6 |
| 5 | 162·3 | 1000·3 | 130·6 | 1130·9 | ·01370 | 72·991 | 4551·3 |
| 5·5 | 166·4 | 997·4 | 134·7 | 1132·1 | ·01505 | 66·428 | 4142·1 |
| 6 | 170·2 | 994·7 | 138·6 | 1133·3 | ·01634 | 61·201 | 3816·2 |
| 6·5 | 173·6 | 992·3 | 142·0 | 1134·3 | ·01762 | 56·761 | 3539·3 |
| 7 | 176·9 | 990·0 | 145·3 | 1135·3 | ·01889 | 52·936 | 3300·9 |
| 7·5 | 180·0 | 987·8 | 148·5 | 1136·3 | ·02016 | 49·610 | 3093·4 |
| 8 | 182·9 | 985·7 | 151·5 | 1137·2 | ·02142 | 46·686 | 2911·1 |
| 8·5 | 185·7 | 983·8 | 154·2 | 1138·0 | ·02268 | 44·097 | 2749·7 |
| 9 | 188·3 | 981·9 | 156·9 | 1138·8 | ·02394 | 41·777 | 2605·0 |
| 9·5 | 190·8 | 980·1 | 159·4 | 1139·5 | ·02547 | 39·261 | 2448·1 |
| 10 | 193·3 | 978·4 | 161·9 | 1140·3 | ·02642 | 37·845 | 2359·8 |
| 10·5 | 195·6 | 976·7 | 164·3 | 1141·0 | ·02767 | 36·145 | 2253·8 |
| 11 | 197·8 | 975·2 | 166·5 | 1141·7 | ·02890 | 34·599 | 2157·4 |
| 11·5 | 200·1 | 973·6 | 168·8 | 1142·4 | ·03026 | 33·045 | 2060·5 |
| 12 | 202·0 | 972·2 | 170·8 | 1143·0 | ·03137 | 31·879 | 1987·7 |
| 12·5 | 204·0 | 970·8 | 172·8 | 1143·6 | ·03260 | 30·678 | 1913·0 |
| 13 | 205·9 | 969·4 | 174·8 | 1144·2 | ·03382 | 29·573 | 1844·0 |
| 13·5 | 207·8 | 968·1 | 176·7 | 1144·8 | ·03504 | 28·536 | 1779·4 |
| 14 | 209·6 | 966·8 | 178·5 | 1145·3 | ·03627 | 27·573 | 1719·1 |
| 14·7 | 212·0 | 965·2 | 180·9 | 1146·1 | ·03797 | 26·360 | 1642·0 |
| 15 | 213·1 | 964·3 | 182·1 | 1146·4 | ·03870 | 25·843 | 1611·6 |
| 16 | 216·3 | 962·1 | 185·3 | 1147·4 | ·04112 | 24·320 | 1516·3 |
| 17 | 219·6 | 959·8 | 188·5 | 1148·3 | ·04253 | 23·513 | 1466·1 |
| 18 | 222·4 | 957·7 | 191·5 | 1149·2 | ·04594 | 21·766 | 1357·4 |
| [illegible] | 225·3 | 955·7 | 194·4 | 1150·1 | ·04834 | 20·687 | 1290·0 |

TABLE 274.—SATURATED STEAM (*continued*).

| Absolute Pressure per Square Inch. | Temperatures. | Total Latent Heat of Steam from Water supplied at 32° F. | Water-heat of Steam (to raise Temperature of Water from 32° F.). | Total Heat of One Pound of Steam from Water supplied at 32° F. | Density, or Weight of One Cubic Foot of Steam. | Volume of One Pound of Steam. | Relative Volume, or Cubic Feet of Steam from One Cubic Foot of Water. |
|---|---|---|---|---|---|---|---|
| 1. | 2. | 6. | 7. | 3. | 8. | 9. | 10. |
| Lbs. | ° Fahr. | Units. | Units. | Units. | Lbs. | Cub. Ft. | Rel. Vol. |
| 20 | 228·0 | 953·8 | 197·1 | 1150·9 | ·05074 | 19·710 | 1229·0 |
| 21 | 230·6 | 951·9 | 199·8 | 1151·7 | ·05311 | 18·828 | 1174·0 |
| 22 | 233·1 | 950·2 | 202·3 | 1152·5 | ·05549 | 18·022 | 1123·8 |
| 23 | 235·5 | 948·5 | 204·7 | 1153·2 | ·05786 | 17·282 | 1077·6 |
| 24 | 237·8 | 946·9 | 207·0 | 1153·9 | ·06023 | 16·603 | 1035·2 |
| 25 | 240·1 | 945·3 | 209·3 | 1154·6 | ·06259 | 15·977 | 996·2 |
| 26 | 242·3 | 943·7 | 211·6 | 1155·3 | ·06495 | 15·401 | 960·2 |
| 27 | 244·4 | 942·2 | 213·6 | 1155·8 | ·06728 | 14·863 | 926·8 |
| 28 | 246·4 | 940·8 | 215·6 | 1156·4 | ·06971 | 14·345 | 894·5 |
| 29 | 248·4 | 939·4 | 217·7 | 1157·1 | ·07196 | 13·896 | 866·5 |
| 30 | 250·4 | 937·9 | 219·9 | 1157·8 | ·07430 | 13·459 | 839·2 |
| 31 | 252·2 | 936·7 | 221·7 | 1158·4 | ·07663 | 13·050 | 813·7 |
| 32 | 254·1 | 935·3 | 223·6 | 1158·9 | ·07894 | 12·666 | 789·8 |
| 33 | 255·9 | 934·0 | 225·5 | 1159·5 | ·08128 | 12·300 | 767·1 |
| 34 | 257·6 | 932·8 | 227·2 | 1160·0 | ·08358 | 11·964 | 746·0 |
| 35 | 259·3 | 931·6 | 228·9 | 1160·5 | ·08590 | 11·640 | 725·9 |
| 36 | 260·9 | 930·5 | 230·5 | 1161·0 | ·08821 | 11·337 | 706·9 |
| 37 | 262·6 | 929·3 | 232·2 | 1161·5 | ·09050 | 11·050 | 689·0 |
| 38 | 264·2 | 928·2 | 233·8 | 1162·0 | ·09282 | 10·773 | 671·7 |
| 39 | 265·8 | 927·1 | 235·4 | 1162·5 | ·09510 | 10·515 | 655·6 |
| 40 | 267·3 | 926·0 | 236·9 | 1162·9 | ·09740 | 10·267 | 640·2 |
| 41 | 268·7 | 924·9 | 238·5 | 1163·4 | ·09946 | 10·054 | 626·9 |
| 42 | 270·2 | 923·9 | 239·9 | 1163·8 | ·1020 | 9·806 | 611·4 |
| 43 | 271·6 | 922·9 | 241·3 | 1164·2 | ·1042 | 9·592 | 598·1 |
| 44 | 273·0 | 921·9 | 242·7 | 1164·6 | ·1065 | 9·386 | 585·3 |
| 45 | 274·4 | 920·9 | 244·2 | 1165·1 | ·1088 | 9·191 | 573·1 |
| 46 | 275·8 | 919·9 | 245·6 | 1165·5 | ·1111 | 9·003 | 561·4 |
| 47 | 277·1 | 919·0 | 246·9 | 1165·9 | ·1134 | 8·821 | 550·0 |
| 48 | 278·4 | 918·1 | 248·2 | 1166·3 | ·1156 | 8·650 | 539·3 |
| 49 | 279·7 | 917·2 | 249·5 | 1166·7 | ·1179 | 8·482 | 528·9 |
| 50 | 281·0 | 916·3 | 250·8 | 1167·1 | ·1202 | 8·322 | 518·9 |
| 51 | 282·3 | 915·4 | 252·1 | 1167·5 | ·1224 | 8·170 | 509·4 |
| 52 | 283·5 | 914·5 | 253·4 | 1167·9 | ·1247 | 8·021 | 500·2 |
| 53 | 284·7 | 913·6 | 254·7 | 1168·3 | ·1269 | 7·880 | 491·[illegible] |

## Table 274.—Saturated Steam (*continued*).

| Absolute Pressure per Square Inch. | Temperatures. | Total Latent Heat of Steam from Water supplied at 32° F. | Water-heat of Steam (to raise Temperature of Water from 32° F.). | Total Heat of One Pound of Steam from Water supplied at 32° F. | Density, or Weight of One Cubic Foot of Steam. | Volume of One Pound of Steam. | Relative Volume, or Cubic Feet of Steam from One Cubic Foot of Water. |
|---|---|---|---|---|---|---|---|
| 1. | 2. | 6. | 7. | 3. | 8. | 9. | 10. |
| Lbs. | ° Fahr. | Units. | Units. | Units. | Lbs. | Cub. Ft. | Rel. Vol. |
| 54 | 285·9 | 912·8 | 255·8 | 1168·6 | ·1292 | 7·741 | 482·7 |
| 55 | 287·1 | 912·0 | 257·0 | 1169·0 | ·1314 | 7·610 | 474·5 |
| 56 | 288·2 | 911·2 | 258·1 | 1169·3 | ·1337 | 7·482 | 466·5 |
| 57 | 289·3 | 910·4 | 259·3 | 1169·7 | ·1357 | 7·370 | 459·5 |
| 58 | 290·4 | 909·6 | 260·4 | 1170·0 | ·1382 | 7·238 | 451·3 |
| 59 | 291·6 | 908·8 | 261·6 | 1170·4 | ·1404 | 7·123 | 444·2 |
| 60 | 292·7 | 908·0 | 262·7 | 1170·7 | ·1426 | 7·011 | 437·2 |
| 61 | 293·8 | 907·2 | 263·9 | 1171·1 | ·1449 | 6·902 | 430·4 |
| 62 | 294·8 | 906·4 | 265·0 | 1171·4 | ·1471 | 6·798 | 423·9 |
| 63 | 295·9 | 905·6 | 266·1 | 1171·7 | ·1493 | 6·696 | 417·5 |
| 64 | 296·9 | 904·9 | 267·1 | 1172·0 | ·1516 | 6·596 | 411·3 |
| 65 | 298·0 | 904·2 | 268·1 | 1172·3 | ·1538 | 6·502 | 405·4 |
| 66 | 299·0 | 903·5 | 269·1 | 1172·6 | ·1560 | 6·410 | 399·7 |
| 67 | 300·0 | 902·8 | 270·1 | 1172·9 | ·1583 | 6·318 | 394·0 |
| 68 | 300·9 | 902·1 | 271·1 | 1173·2 | ·1604 | 6·233 | 388·7 |
| 69 | 301·9 | 901·4 | 272·1 | 1173·5 | ·1627 | 6·147 | 383·3 |
| 70 | 302·9 | 900·8 | 273·0 | 1173·8 | ·1650 | 6·059 | 377·8 |
| 71 | 303·9 | 900·3 | 273·8 | 1174·1 | ·1671 | 5·984 | 373·1 |
| 72 | 304·8 | 899·6 | 274·7 | 1174·3 | ·1693 | 5·905 | 368·2 |
| 73 | 305·7 | 898·9 | 275·7 | 1174·6 | ·1716 | 5·829 | 363·5 |
| 74 | 306·5 | 898·2 | 276·7 | 1174·9 | ·1738 | 5·754 | 358·8 |
| 75 | 307·5 | 897·5 | 277·7 | 1175·2 | ·1760 | 5·683 | 354·4 |
| 76 | 308·4 | 896·8 | 278·6 | 1175·4 | ·1782 | 5·610 | 349·8 |
| 77 | 309·3 | 896·1 | 279·6 | 1175·7 | ·1803 | 5·544 | 345·7 |
| 78 | 310·2 | 895·5 | 280·5 | 1176·0 | ·1826 | 5·476 | 341·5 |
| 79 | 311·1 | 894·9 | 281·4 | 1176·3 | ·1848 | 5·411 | 337·4 |
| 80 | 312·0 | 894·3 | 282·2 | 1176·5 | ·1870 | 5·348 | 333·5 |
| 81 | 312·8 | 893·7 | 283·1 | 1176·8 | ·1892 | 5·286 | 329·6 |
| 82 | 313·6 | 893·1 | 284·0 | 1177·1 | ·1912 | 5·230 | 326·1 |
| 83 | 314·5 | 892·5 | 284·9 | 1177·4 | ·1936 | 5·167 | 322·2 |
| 84 | 315·3 | 892·0 | 285·6 | 1177·6 | ·1957 | 5·109 | 318·5 |
| 85 | 316·1 | 891·4 | 286·5 | 1177·9 | ·1980 | 5·052 | 315·0 |
| 86 | 316·9 | 890·8 | 287·3 | 1178·1 | ·2001 | 4·996 | 311·5 |
| | 317·8 | 890·2 | 288·2 | 1178·4 | ·2023 | 4·942 | 308·2 |

TABLE 274.—SATURATED STEAM (*continued*).

| Absolute Pressure per Square Inch. 1 | Temperatures. 2. | Total Latent Heat of Steam from Water supplied at 32° F. 6. | Water-heat of Steam (to raise Temperature of Water from 33° F.). 7. | Total Heat of One Pound of Steam from Water supplied at 32° F. 3. | Density, or Weight of One Cubic Foot of Steam 8. | Volume of One Pound of Steam. 9. | Relative Volume, or Cubic Feet of Steam from One Cubic Foot of Water. 10. |
|---|---|---|---|---|---|---|---|
| Lbs. | ° Fahr. | Units. | Units. | Units. | Lbs. | Cub. Ft. | Rel. Vol. |
| 88 | 318·6 | 889·6 | 289·0 | 1178·6 | ·2046 | 4·889 | 304·8 |
| 89 | 319·4 | 889·0 | 289·9 | 1178·9 | ·2067 | 4·837 | 301·6 |
| 90 | 320·2 | 888·5 | 290·6 | 1179·1 | ·2088 | 4·790 | 298·6 |
| 91 | 321·0 | 887·9 | 291·4 | 1179·3 | ·2111 | 4·737 | 295·4 |
| 92 | 321·7 | 887·3 | 292·2 | 1179·5 | ·2133 | 4·688 | 292·3 |
| 93 | 322·5 | 886·8 | 293·0 | 1179·8 | ·2154 | 4·642 | 289·4 |
| 94 | 323·3 | 886·3 | 293·7 | 1180·0 | ·2176 | 4·595 | 286·5 |
| 95 | 324·1 | 885·8 | 294·5 | 1180·3 | ·2198 | 4·549 | 283·7 |
| 96 | 324·8 | 885·2 | 295·3 | 1180·5 | ·2220 | 4·505 | 280·9 |
| 97 | 325·6 | 884·6 | 296·2 | 1180·8 | ·2241 | 4·462 | 278·2 |
| 98 | 326·3 | 884·1 | 296·9 | 1181·0 | ·2263 | 4·419 | 275·5 |
| 99 | 327·1 | 883·6 | 297·6 | 1181·2 | ·2286 | 4·375 | 272·8 |
| 100 | 327·9 | 883·1 | 298·3 | 1181·4 | ·2307 | 4·335 | 270·3 |
| 101 | 328·5 | 882·6 | 299·0 | 1181·6 | ·2329 | 4·305 | 267·8 |
| 102 | 329·1 | 882·1 | 299·7 | 1181·8 | ·2350 | 4·256 | 265·4 |
| 103 | 329·9 | 881·6 | 300·4 | 1182·0 | ·2372 | 4·216 | 262·9 |
| 104 | 330·6 | 881·1 | 301·1 | 1182·2 | ·2393 | 4·178 | 260·5 |
| 105 | 331·3 | 880·7 | 301·7 | 1182·4 | ·2415 | 4·140 | 258·2 |
| 106 | 331·9 | 880·2 | 302·4 | 1182·6 | ·2437 | 4·104 | 255·9 |
| 107 | 332·6 | 879·7 | 303·1 | 1182·8 | ·2458 | 4·068 | 253·6 |
| 108 | 333·3 | 879·2 | 303·8 | 1183·0 | ·2480 | 4·033 | 251·4 |
| 109 | 334·0 | 878·7 | 304·6 | 1183·3 | ·2502 | 3·998 | 249·3 |
| 110 | 334·6 | 878·3 | 305·2 | 1183·5 | ·2523 | 3·963 | 247·1 |
| 111 | 335·3 | 877·8 | 305·9 | 1183·7 | ·2545 | 3·930 | 245·0 |
| 112 | 336·0 | 877·3 | 306·6 | 1183·9 | ·2566 | 3·897 | 243·0 |
| 113 | 336·7 | 876·8 | 307·3 | 1184·1 | ·2588 | 3·865 | 241·0 |
| 114 | 337·4 | 876·3 | 308·0 | 1184·3 | ·2610 | 3·832 | 238·9 |
| 115 | 338·0 | 875·9 | 308·6 | 1184·5 | ·2631 | 3·801 | 237·0 |
| 116 | 338·6 | 875·5 | 309·2 | 1184·7 | ·2653 | 3·770 | 235·0 |
| 117 | 339·3 | 875·0 | 309·9 | 1184·9 | ·2674 | 3·740 | 233·2 |
| 118 | 339·9 | 874·5 | 310·6 | 1185·1 | ·2696 | 3·710 | 231·3 |
| 119 | 340·5 | 874·1 | 311·2 | 1185·3 | ·2717 | 3·681 | 229·5 |
| 120 | 341·1 | 873·7 | 311·7 | 1185·4 | ·2738 | 3·652 | 227·7 |
| 121 | 341·8 | 873·2 | 312·4 | 1185·6 | ·2760 | 3·623 | 225·9 |

## TABLE 274.—SATURATED STEAM (*continued*).

| Absolute Pressure per Square Inch. 1. | Temperatures. 2. | Total Latent Heat of Steam from Water supplied at 32° F. 6. | Water-heat of Steam (to raise Temperature of Water from 32° F.). 7. | Total Heat of One Pound of Steam from Water supplied at 32° F. 3. | Density, or Weight of One Cubic Foot of Steam. 8. | Volume of One Pound of Steam. 9. | Relative Volume, or Cubic Feet of Steam from One Cubic Foot of Water. 10. |
|---|---|---|---|---|---|---|---|
| Lbs. | ° Fahr. | Units. | Units. | Units. | Lbs. | Cub. Ft. | Rel. Vol. |
| 122 | 342·4 | 872·8 | 313·0 | 1185·8 | ·2781 | 3·595 | 224·2 |
| 123 | 343·0 | 872·3 | 313·7 | 1186·0 | ·2803 | 3·567 | 222·4 |
| 124 | 343·6 | 871·9 | 314·3 | 1186·2 | ·2824 | 3·541 | 220·8 |
| 125 | 344·2 | 871·5 | 314·9 | 1186·4 | ·2846 | 3·514 | 219·1 |
| 126 | 344·8 | 871·1 | 315·5 | 1186·6 | ·2867 | 3·488 | 217·5 |
| 127 | 345·4 | 870·7 | 316·1 | 1186·8 | ·2889 | 3·462 | 215·8 |
| 128 | 346·0 | 870·2 | 316·7 | 1186·9 | ·2910 | 3·436 | 214·3 |
| 129 | 346·6 | 869·8 | 317·3 | 1187·1 | ·2931 | 3·411 | 212·7 |
| 130 | 347·2 | 869·4 | 317·9 | 1187·3 | ·2951 | 3·388 | 211·3 |
| 131 | 347·8 | 869·0 | 318·5 | 1187·5 | ·2974 | 3·362 | 209·7 |
| 132 | 348·3 | 868·6 | 319·0 | 1187·6 | ·2996 | 3·338 | 208·1 |
| 133 | 348·9 | 868·2 | 319·6 | 1187·8 | ·3017 | 3·315 | 206·7 |
| 134 | 349·5 | 867·8 | 320·2 | 1188·0 | ·3038 | 3·291 | 205·2 |
| 135 | 350·1 | 867·4 | 320·8 | 1188·2 | ·3060 | 3·268 | 203·8 |
| 136 | 350·6 | 867·0 | 321·3 | 1188·3 | ·3080 | 3·246 | 202·4 |
| 137 | 351·2 | 866·6 | 321·9 | 1188·5 | ·3102 | 3·224 | 201·0 |
| 138 | 351·8 | 866·2 | 322·5 | 1188·7 | ·3123 | 3·201 | 199·6 |
| 139 | 352·4 | 865·8 | 323·1 | 1188·9 | ·3145 | 3·180 | 198·3 |
| 140 | 352·9 | 865·4 | 323·6 | 1189·0 | ·3166 | 3·159 | 197·0 |
| 141 | 353·5 | 865·0 | 324·2 | 1189·2 | ·3187 | 3·138 | 195·6 |
| 142 | 354·0 | 864·6 | 324·8 | 1189·4 | ·3209 | 3·117 | 194·3 |
| 143 | 354·5 | 864·2 | 325·4 | 1189·6 | ·3230 | 3·096 | 193·1 |
| 144 | 355·0 | 863·9 | 325·8 | 1189·7 | ·3251 | 3·076 | 191·8 |
| 145 | 355·6 | 863·5 | 326·4 | 1189·9 | ·3272 | 3·056 | 190·6 |
| 146 | 356·1 | 863·1 | 326·9 | 1190·0 | ·3293 | 3·037 | 189·4 |
| 147 | 356·7 | 862·7 | 327·5 | 1190·2 | ·3315 | 3·017 | 188·1 |
| 148 | 357·2 | 862·3 | 328·0 | 1190·3 | ·3336 | 2·998 | 186·9 |
| 149 | 357·8 | 861·9 | 328·6 | 1190·5 | ·3357 | 2·979 | 185·7 |
| 150 | 358·3 | 861·5 | 329·2 | 1190·7 | ·3378 | 2·960 | 184·6 |
| 151 | 359·0 | 861·1 | 329·8 | 1190·9 | ·3400 | 2·941 | 183·4 |
| 152 | 359·5 | 860·7 | 330·3 | 1191·0 | ·3421 | 2·923 | 182·2 |
| 153 | 360·0 | 860·4 | 330·8 | 1191·2 | ·3442 | 2·905 | 181·2 |
| 154 | 360·5 | 860·0 | 331·4 | 1191·4 | ·3463 | 2·887 | 180·0 |
| 155 | 361·1 | 859·6 | 331·9 | 1191·5 | ·3484 | 2·870 | 179·0 |

TABLE 274.—SATURATED STEAM (*continued*).

| Absolute Pressure per Square Inch. 1. | Temperatures. 2. | Total Latent Heat of Steam from Water supplied at 32° F. 6. | Water-heat of Steam (to raise Temperature of Water from 32° F.). 7. | Total Heat of One Pound of Steam from Water supplied at 32° F. 3. | Density, or Weight of One Cubic Foot of Steam. 8. | Volume of One Pound of Steam. 9. | Relative Volume, or Cubic Feet of Steam from One Cubic Foot of Water. 10. |
|---|---|---|---|---|---|---|---|
| Lbs. | ° Fahr. | Units. | Units. | Units. | Lbs. | Cub. Ft. | Rel. Vol. |
| 156 | 361·6 | 859·2 | 332·5 | 1191·7 | ·3505 | 2·853 | 177·9 |
| 157 | 362·1 | 858·9 | 332·9 | 1191·8 | ·3527 | 2·836 | 176·8 |
| 158 | 362·6 | 858·5 | 333·5 | 1192·0 | ·3548 | 2·818 | 175·7 |
| 159 | 363·1 | 858·1 | 334·0 | 1192·1 | ·3569 | 2·802 | 174·7 |
| 160 | 363·6 | 857·8 | 334·5 | 1192·3 | ·3590 | 2·785 | 173·7 |
| 165 | 366·0 | 856·2 | 336·7 | 1192·9 | ·3696 | 2·706 | 168·7 |
| 170 | 368·2 | 854·5 | 339·2 | 1193·7 | ·3801 | 2·631 | 164·1 |
| 175 | 370·8 | 852·9 | 341·5 | 1194·4 | ·3905 | 2·559 | 159·7 |
| 180 | 372·9 | 851·3 | 343·8 | 1195·1 | ·4011 | 2·493 | 155·5 |
| 185 | 375·3 | 849·6 | 346·2 | 1195·8 | ·4115 | 2·430 | 151·5 |
| 190 | 377·5 | 848·0 | 348·5 | 1196·5 | ·4220 | 2·370 | 147·8 |
| 195 | 379·7 | 846·5 | 350·7 | 1197·2 | ·4324 | 2·313 | 144·2 |
| 200 | 381·7 | 845·0 | 352·8 | 1197·8 | ·4419 | 2·263 | 141·1 |

## STEAM ENGINES AND BOILERS.

### Steam Engines.

The work of steam in the cylinder is in two parts:—the work during admission, and the work done during expansion after the steam is cut off.

The absolute work done during admission is,

$a\mathrm{P}l$, or a $\mathrm{P}(l'-c)$ . . . . . . . . . (1)

The absolute work done during expansion to the end of the stroke, is.

$a\mathrm{P}l+$ hyp. log. R′ . . . . . . . . . (2)

Here, for purposes of calculation, the hyperbolic law of expansion is assumed; according to which the pressure varies inversely as the volume.

The sum for these two quantities gives the total absolute work for one stroke: or, by reduction,

$w=a\mathrm{P}[l'\,(1+\text{hyp. log. R}')-c]$ . . . . . (

In this expression an absolute vacuum for the whole of the return stroke is supposed. But there is the work of back pressure of exhaust and compression to be deducted; that is :—

$$w' = a\,p'\,L. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

and the net work is $w - w'$, or

$$W = a[P\,(l'\,(1 + \text{hyp. log. } R') - c) - p'\,L]\,. \quad . \quad . \quad (5)$$

In this expression it is assumed that the whole of the steam is expanded to the end of the steam-stroke; or that there is no material loss by commencing the exhaustion of steam before the end of the stroke.

$L$ = length of stroke, in feet.

$l$ = period of admission, or length cut off, excluding clearance, in feet.

$c$ = total clearance for one end of the cylinder, in parts of a foot of the stroke.

$L'$ = length of stroke plus clearance.

$l'$ = period of admission plus clearance.

$R'$ = actual ratio of expansion.

$a$ = area of piston, in square inches.

$P$ = absolute pressure during admission, supposed uniform, in pounds per square inch of piston area.

$p$ = average absolute positive pressure for the whole stroke, in pounds per square inch.

$p'$ = average absolute back pressure for whole stroke, in pounds per square inch.

$w$ = whole absolute work for one stroke, per square inch, in foot pounds.

$w'$ = absolute work of back pressure for one stroke, per square inch in foot pounds.

$W$ = net work for one stroke per square inch in foot pounds.

$n$ = number of double strokes or revolutions of the engine.

The net horse-power of a double-acting steam-engine, for which the work has been calculated as above, is expressed by the following quantity :—

$$\frac{W \times n \times 2 \times a}{33000}\ ;\ \text{or}\ \frac{Wna}{16500} \quad . \quad . \quad . \quad (6)$$

To calculate the net horse-power from the ordinary indicator diagram, in which all deviations from the above ideal performance are aggregated, find the effective mean pressure $p - p'$, per square inch on the piston for the whole of the stroke, Thus :—

$$\text{I.H.P.} = \frac{(p - p') \times a \times 2L \times n}{33000}\ ;\ \text{or} \quad . \quad (7)$$

$$\text{I.H.P.} = \frac{(p - p')\,aLn}{16500} \quad . \quad . \quad . \quad . \quad (8)$$

In practice, the value $(p - p')$ may be taken by direct measurements of the net area of pressure circumscribed by the diagram.

TABLE 275.—WORK OF ONE POUND OF STEAM IN THE CYLINDER.

| Point of Admission, or Cut-off. | | Total Absolute Work done. | Steam per Total Absolute Horse-Power per Hour. | Average Total Pressure, that for 100 per cent. Admission being 1·000. | Net Capacity of Cylinder per lb. of 100 lbs. Steam (absolute pressure) admitted in one Stroke. |
|---|---|---|---|---|---|
| Per cent. | Fraction. | Ft. Lbs. | Pounds. | | Cubic Feet. |
| 90 | or $\frac{9}{10}$ | 63,850 | 31·0 | ·996 | 4·45 |
| 80 | ,, $\frac{4}{5}$ | 70,246 | 28·2 | ·980 | 4·98 |
| 75 | ,, $\frac{3}{4}$ | 73,513 | 26·9 | ·969 | 5·26 |
| 70 | | 77,242 | 25·6 | ·953 | 5·63 |
| 66·6 | ,, $\frac{2}{3}$ | 79,555 | 24·9 | ·942 | 5·87 |
| 62·5 | ,, $\frac{5}{8}$ | 83,055 | 23·8 | ·925 | 6·23 |
| 60 | | 85,125 | 23·3 | ·913 | 6·47 |
| 55 | | 89,357 | 22·2 | ·888 | 6·98 |
| 50 | ,, $\frac{1}{2}$ | 94,200 | 21·0 | ·860 | 7·61 |
| 45 | | 98,849 | 20·0 | ·827 | 8·30 |
| 40 | ,, $\frac{2}{5}$ | 104,406 | 19·0 | ·787 | 9·23 |
| 37·6 | ,, $\frac{3}{8}$ | 107,050 | 18·5 | ·766 | 9·71 |
| 33·3 | ,, $\frac{1}{3}$ | 112,220 | 17·7 | ·726 | 10·72 |
| 30 | ,, $\frac{3}{10}$ | 116,885 | 16·9 | ·692 | 11·74 |
| 25 | ,, $\frac{1}{4}$ | 124,066 | 16·0 | ·637 | 13·56 |
| 20 | ,, $\frac{1}{5}$ | 132,770 | 14·9 | ·567 | 16·19 |
| 16·7 | ,, $\frac{1}{6}$ | 138,130 | 14·34 | ·526 | 18·21 |
| 14·3 | ,, $\frac{1}{7}$ | 142,180 | 13·92 | ·488 | 20·23 |
| 12·5 | ,, $\frac{1}{8}$ | 146,325 | 13·53 | ·457 | 22·25 |
| 11·1 | ,, $\frac{1}{9}$ | 148,940 | 13·29 | ·432 | 23·87 |
| 10·0 | ,, $\frac{1}{10}$ | 151,370 | 13·08 | ·413 | 25·49 |
| 9·0 | ,, $\frac{1}{11}$ | 152,595 | 12·98 | ·398 | 26·71 |
| 8·3 | ,, $\frac{1}{12}$ | 155,200 | 12·75 | ·381 | 28·33 |
| 7·7 | ,, $\frac{1}{13}$ | 156,960 | 12·61 | ·369 | 29·54 |
| 7·1 | ,, $\frac{1}{14}$ | 157,975 | 12·53 | ·357 | 30·76 |
| 6·7 | ,, $\frac{1}{15}$ | 158,414 | 12·25 | ·348 | 31·57 |
| 6·4 | ,, $\frac{1}{16}$ | 159,433 | 11·83 | ·342 | 32·38 |

The absolute work done by one pound of steam of absolute pressure varying from 65 lbs. to 160 lbs., worked expansively, with the consumption per absolute horse-power are given approximately in the Table 275. No correction need be made

for clearance space, nor for the resistance of compression, as the period of compression can be so adjusted that the loss by resistance is compensated by the gain of exhaust steam shut into the cylinder. But, for the back pressure of exhaust, whether from the condenser or from the atmosphere, suitable allowance is to be made. The pressure during admission into the cylinder is supposed to be uniform; and the steam is supposed to be expanded to the end of the stroke.

The values in the last column.—net capacity per pound of steam of 100 lbs. absolute pressure per square inch—are to be modified for steam of other pressures in the ratio of the volume of 100 lbs. steam to that of steam of other pressures. The multipliers are here given for absolute pressures of from 65lbs. to 160lbs.:—

| Pressures. | Multipliers. | Pressures. | Multipliers. | Pressures. | Multipliers. |
|---|---|---|---|---|---|
| Lbs. | | Lbs. | | Lbs. | |
| 65 | 1·50 | 90 | 1·11 | 130 | ·781 |
| 70 | 1·40 | 95 | 1·05 | 140 | ·730 |
| 75 | 1·31 | 100 | 1·00 | 150 | ·683 |
| 80 | 1·24 | 110 | ·917 | 160 | ·644 |
| 85 | 1·17 | 120 | ·843 | | |

The effective mean pressure in ordinary non-condensing cylinders, with ordinary slide-valve and excentric motion, or a like motion, working at average speeds, is given approximately by the equation:—

$$p = 13{\cdot}5\sqrt{a} - 28 \quad . \quad . \quad . \quad . \quad (9)$$

$p$ = effective mean pressure, in per cent. of the maximum pressure of admission.

$a$ = period of admission, in per cent. of the length of stroke.

For a speed of 560 feet of piston per minute, the formula is applicable without material error. For lower speeds, the values of the effective mean pressures are slightly too small; and for higher speeds slightly too great. The rule applies without material error to periods of admission of from 10 per cent. to 75 per cent., and to maximum pressures in the cylinder of from 60 lbs. to 100 lbs. or even 150 lbs. per square inch.

The Table 276 has been calculated by means of the above formula:—

TABLE 276.—EFFECTIVE MEAN PRESSURES IN NON-CONDENSING CYLINDER, FOR VARIOUS PERIODS OF ADMISSION, FROM PRACTICE.

("Railway Machinery.")

| Period of Admission, in per cent. of the Stroke. | Effective Mean Pressure. in per cent. of Maximum Pressure. | Period of Admission, in parts of the Stroke. | Effective Mean Pressure, in parts of Maximum Pressure. |
|---|---|---|---|
| Per Cent. | Per Cent. | Fraction. | Fraction. |
| 10 | 15 | 1-10th | 1-7th fully |
| 12·5 | 20 | 1-8th | 1-5th |
| 15 | 24 | ... | ... |
| 17·5 | 28 | 1-6th | 1-4th |
| 20 | 32 | 1-5th | 1-3rd |
| 25 | 40 | 1-4th | 1-2·5th part |
| 30 | 46 | ... | ... |
| 35 | 52 | 1-3rd | 1-2nd |
| 40 | 57 | ... | ... |
| 45 | 62 | ... | ... |
| 50 | 67 | 1-2nd | 2-3rds |
| 55 | 72 | ... | ... |
| 60 | 77 | ... | ... |
| 65 | 81 | 2-3rds | 4-5ths |
| 70 | 85 | ... | ... |
| 75 | 89 | 3-4ths | 9-10ths |

When gaseous steam is expanded in the cylinder, it follows approximately the adiabatic law, the essential condition of which is that the cylinder should be non-conductive. The formula for gaseous steam is as follows :—

$$P' = P \times \left(\frac{v'}{v}\right)^{1\cdot 294} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (10)$$

P = absolute pressure, say in pounds per square inch, for the given volume V.

P′ = absolute pressure, in pounds per square inch, for any other volume V′.

V = initial volume, say in cubic feet.

V′ = volume by expansion, in cubic feet.

Any number of pressures with expansion may be calculated by the formula, and thus the expansion-curve may be determined; for comparison with expansive curves of ordinary practice, using saturated steam.

## Valve Motions.

In slide-valves for the distribution of the steam in the cylinder—taking an ordinary valve for a three-port cylinder—the lap, or cover, is the length by which the valve when in its middle position, overlaps the steam port at each end; the lead is the length of opening of each steam port for steam at the beginning of the stroke; and the linear advance of the valve is the sum of the lap and the lead. Inside lap is

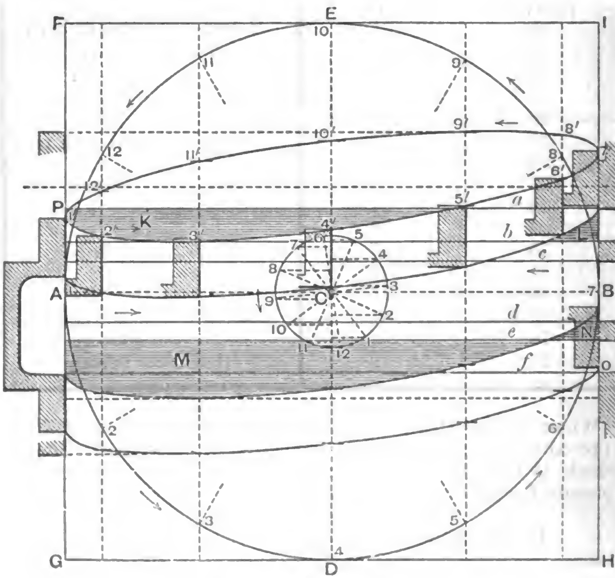



FIG. 79.—Valve-diagram.

occasionally applied to slide-valves; it is the width by which the inner edge of the valve, when the valve is in its middle position, overlaps the inner edge of the steam port. The angular advance is the angle formed by the excentric with its position at its half-stroke, when the piston is at the commencement of its stroke.

The movements of sliding valves worked by an excentric or by an equivalent motion—as that of ordinary expansion link-

motions—may be established by means of diagrams, exemplified by figure 79.

To construct this diagram, draw A B equal to the length of stroke of the piston, and bisect it at C. On C as a centre, with C A or C B as a radius, describe a circle representing the path of the crank-pin; and describe also the circle D E for that of the centre of the excentric. Through C draw the perpendicular D E, and construct a square on the large circle. Let the side H I be taken to represent the ordinary three-ported valve-face of the cylinder, and set off the ports and bars above and below the centre-line A B, and through the points draw the parallels *a*, *b*, *c*, *d*, *e*, *f*. The movement of the excentric is taken as horizontal, in the direction A B, and is directly determined by the position of the centre of the excentric; and that of the valve is for convenience taken as in the direction of D E. The middle position of the valve is represented by the dot-lines across the diagram parallel to A B; which represent its total length, and they overlie the outer edges *a* and *f* of the steam ports, by a length representing the lap. For the first position of the valve—at the beginning of the stroke—it is placed at a length equal to the linear advance, or the lap plus the lead, from its middle position, as measured on the perpendicular drawn from the corresponding first position of the excentric, No. 1. to the vertical centre-line E D. Divide both circles into 12 parts, numbered in succession from point No. 1 to point No. 12, and draw radial lines through the points of division, to represent the successive simultaneous positions of the crank and the excentric. The transverse lines drawn through the points of division on the larger circle parallel to D E, represent the corresponding positions of the piston during the inward and outward strokes; and the perpendiculars drawn to the line D E from the points of division of the smaller circle, measure the simultaneous longitudinal movements of the excentric, or the distances of the valve-edges above or below their middle positions. These are set off on the ordinates parallel to D E, and they range in elliptic curves as inscribed on the diagram, representing the whole movements of the valve for a double stroke of the piston, or one revolution of the crank.

Zeuner's valve-diagram fig. 80, affords a simple means of settling the points of the distribution of steam. Draw two lines, A B and C D, at right angles, intersecting at O; and with the radius A O, equal to half the travel of the valve, describe the circle A B, taken to represent the path of the crank-pin. Set off the diameter *a* O *a*′, at the angle *a* O C, equal to the angular advance of the excentric; and on the radii *a* O and O *a*′ describe the circles *a* O and O *a*′. On the

centre O, with the radius O $b$, equal to the outside lap of the valve, describe a circle cutting the circle $a$ O at $b$ and $c$; and from these points of intersection, draw the radii O $f$ and O $g$. Draw the diameter $d$ O $e$ at right angles to the diameter $a$ O $a'$. Taking A B for the stroke of the piston, the point $f$, is the position of the crank-pin when the valve opens for lead at

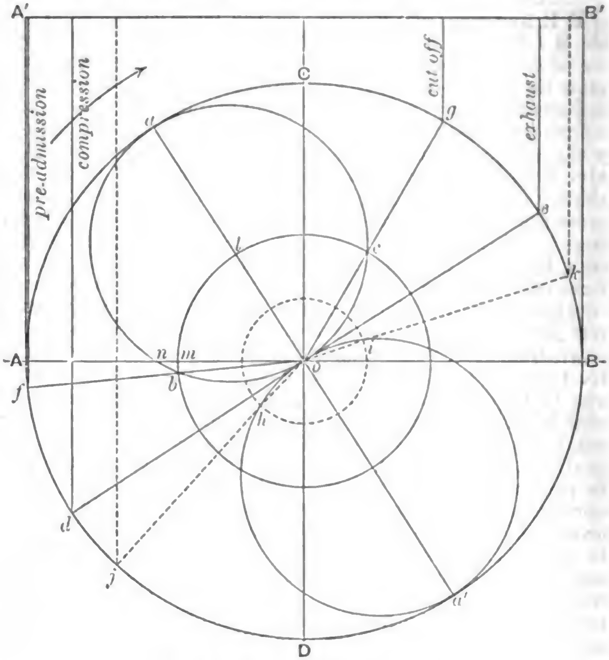



FIG. 80.—Zeuner's Valve-diagram.

A, the beginning of the stroke; $g$ is the position when the steam is cut off; $e$ is the position when the valve is opened for exhaust; and $d$ is the position when the exhaust side of the valve is closed for compression. In this case, there is no inside lap.

For a case of inside lap on the valve, describe the circle $h$ $i$, with a radius equal to the inside lap, cutting the circle O $a'$ at $h$ and $i$, and through these points draw the radii O $j$, and O $k$. The point $k$, in the outer circle, is the position of the crank-

pin when the exhaust is opened, and the point $j$ is the position when it is closed for compression.

Draw a parallel A′ B′ to the base-line A B, and draw ordinates to it from the several points of the distribution in

TABLE 277.—CORRECTIONS FOR THE POSITION OF THE PISTON, DUE TO THE OBLIQUITY OF THE CONNECTING-ROD.

| Distance of Piston from Commencement of Stroke, as represented by the progress longitudinally of the Crank, in percentage of the Stroke. | | Corrections for Connecting-Rods of Several Lengths related to the Length of the Crank, in percentages of the Whole Stroke. | | |
|---|---|---|---|---|
| | | Four Lengths of Crank. | Six Lengths of Crank. | Eight Lengths of Crank. |
| Per Cent. | Per Cent. | Per Cent. | Per Cent. | Per Cent. |
| 0 | 100 | 0 | 0 | 0 |
| 2 | 98 | $0\frac{1}{2}$ | $0\frac{1}{4}$ | $0\frac{1}{4}$ |
| 4 | 96 | 1 | $0\frac{1}{2}$ | $0\frac{1}{2}$ |
| 6 | 94 | $1\frac{1}{2}$ | 1 | $0\frac{3}{4}$ |
| 8 | 92 | 2 | $1\frac{1}{4}$ | 1 |
| 10 | 90 | $2\frac{1}{4}$ | $1\frac{1}{2}$ | 1 |
| 12 | 88 | $2\frac{3}{4}$ | $1\frac{3}{4}$ | $1\frac{1}{2}$ |
| 14 | 86 | 3 | 2 | $1\frac{1}{2}$ |
| 16 | 84 | $3\frac{1}{2}$ | $2\frac{1}{4}$ | $1\frac{3}{4}$ |
| 18 | 82 | $3\frac{3}{4}$ | $2\frac{1}{2}$ | 2 |
| 20 | 80 | 4 | $2\frac{3}{4}$ | 2 |
| 22 | 78 | $4\frac{1}{2}$ | 3 | $2\frac{1}{4}$ |
| 24 | 76 | $4\frac{1}{2}$ | 3 | $2\frac{1}{4}$ |
| 26 | 74 | 5 | $3\frac{1}{4}$ | $2\frac{1}{2}$ |
| 28 | 72 | 5 | $3\frac{1}{4}$ | $2\frac{1}{2}$ |
| 30 | 70 | $5\frac{1}{4}$ | $3\frac{1}{2}$ | $2\frac{1}{2}$ |
| 32 | 68 | $5\frac{1}{2}$ | $3\frac{3}{4}$ | $2\frac{3}{4}$ |
| 34 | 66 | $5\frac{3}{4}$ | $3\frac{3}{4}$ | 3 |
| 36 | 64 | 6 | 4 | 3 |
| 38 | 62 | 6 | 4 | 3 |
| 40 | 60 | 6 | 4 | 3 |
| 42 | 58 | $6\frac{1}{4}$ | 4 | 3 |
| 44 | 56 | $6\frac{1}{4}$ | $4\frac{1}{4}$ | 3 |
| 46 | 54 | $6\frac{1}{4}$ | $4\frac{1}{4}$ | 3 |
| 48 | 52 | $6\frac{1}{2}$ | $4\frac{1}{4}$ | $3\frac{1}{4}$ |
| 50 | 50 | $6\frac{1}{2}$ | $4\frac{1}{4}$ | $3\frac{1}{4}$ |

the circle A B. The intersections of these ordinates with the parallel A′ B′ give the points of the distribution for the double stroke of the piston.

The distribution is affected by the obliquity of the connect-

ing-rod, insomuch that during the front stroke—that is the stroke made towards the crank—the piston is in advance of its normal position, as represented by the progress longitudinally of the crank-pin ; and during the back stroke, it is behind its normal position. The corrections in per cent. of the stroke are given in Table 277, for three different lengths of connecting-rod, in proportion to the length of the crank. They are additive for front strokes, and subtractive for back strokes. They have been calculated by means of the formula (11) (*Railway Machinery*).

$$x = a\,r - \sqrt{(a^2-1)r^2+b^2} \quad . \quad . \quad . \ (11)$$

$a$ = length of connecting-rod in parts of that of the crank.
$b$ = distance of piston from the middle of the stroke as represented by the progress longitudinally of the crank.
$r$ = length of crank.
$x$ = the correction.

### Rules for Valves.

1. *For the angular advance of the excentric.* Divide the linear advance by the half-travel ; the quotient is the sine of the angle of advance ; and the angle, which is acute, may be found in a table of sines.

2. *For the period of admission or point of cut-off.* Divide the lap by the half-travel of the valve ; the quotient is the sine of the angle of the excentric at the instant of cut-off ; the angle is obtuse and is found in a table of sines. From this angle subtract the angle of advance as found by Rule I. ; the difference is the angle of the crank. If this angle is obtuse, add 1 to its cosine ; if acute, subtract it from 1. The product of the sum or the difference by 50, is the percentage of admission.

3. *For the period of compression.* Subtract the cosine of the angle of advance from 1, and multiply by 50, to find the percentage of the period of compression.

These rules may be employed for link-motions ; and generally for all valve-motions based on the motion of excentrics.

By means of the first and second rules, the following table 276, has been calculated with a constant lead, $\frac{5}{16}$ inch.

When it is desired that the lap, lead, and travel of the slide-valve should bear constant ratios to each other, the following general rule is useful :—

4. Given the travel, to find the lap and lead suitable for an admission of about 75 per cent. of the stroke.

1st for lap, multiply the travel by 22, and divide by 100.
2nd for lead, multiply the travel by 7, and divide by 100.
By this rule, the Table 278, has been calculated.

### TABLE 278.—LAP AND LEAD OF SLIDE-VALVES, PROPORTIONED FOR VARIOUS TRAVELS, FOR AN ADMISSION OF ABOUT 75 PER CENT. OF THE STROKE.

| Travel of Valve. | Lap. | Lead. | Travel of Valve. | Lap. | Lead. |
|---|---|---|---|---|---|
| Inches. | Inches. | Inch. | Inches. | Inches. | Inch |
| $1\frac{1}{2}$ | ·33 or $\frac{5}{16}$ $\frac{1}{64}$ | ·10 or $\frac{3}{32}$ | $3\frac{1}{4}$ | ·71 or $\frac{11}{16}$ $\frac{1}{64}$ | ·22 or $\frac{3}{16}$ $\frac{1}{32}$ |
| $1\frac{5}{8}$ | ·36 „ $\frac{5}{16}$ $\frac{3}{64}$ | ·11 „ $\frac{1}{16}$ $\frac{3}{64}$ | $3\frac{1}{2}$ | ·77 „ $\frac{12}{16}$ $\frac{1}{64}$ | ·24 „ $\frac{3}{16}$ $\frac{3}{64}$ |
| $1\frac{3}{4}$ | ·38 „ $\frac{6}{16}$ | ·12 „ $\frac{1}{8}$ | $3\frac{3}{4}$ | ·82 „ $\frac{13}{16}$ | ·26 „ $\frac{1}{4}$ |
| $1\frac{7}{8}$ | ·41 „ $\frac{6}{16}$ $\frac{1}{32}$ | ·13 „ $\frac{1}{8}$ | 4 | ·88 „ $\frac{14}{16}$ | ·28 „ $\frac{1}{4}$ $\frac{1}{32}$ |
| 2 | ·44 „ $\frac{7}{16}$ | ·14 „ $\frac{1}{8}$ $\frac{1}{64}$ | $4\frac{1}{4}$ | ·93 „ $\frac{15}{16}$ | ·30 „ $\frac{1}{4}$ $\frac{3}{64}$ |
| $2\frac{1}{8}$ | ·47 „ $\frac{7}{16}$ $\frac{1}{32}$ | ·15 „ $\frac{1}{8}$ $\frac{1}{32}$ | $4\frac{1}{2}$ | ·99 „ 1·00 | ·31 „ $\frac{5}{16}$ |
| $2\frac{1}{4}$ | ·50 „ $\frac{1}{2}$ | ·16 „ $\frac{1}{8}$ $\frac{1}{32}$ | $4\frac{3}{4}$ | 1·04 „ $1\frac{3}{64}$ | ·33 „ $\frac{5}{16}$ $\frac{1}{64}$ |
| $2\frac{3}{8}$ | ·52 „ $\frac{8}{16}$ $\frac{1}{64}$ | ·17 „ $\frac{1}{8}$ $\frac{3}{64}$ | 5 | 1·10 „ $1\frac{3}{32}$ | ·35 „ $\frac{5}{16}$ $\frac{1}{32}$ |
| $2\frac{1}{2}$ | ·55 „ $\frac{8}{16}$ $\frac{3}{64}$ | ·17 „ $\frac{1}{8}$ $\frac{3}{64}$ | $5\frac{1}{4}$ | 1·15 „ $1\frac{1}{8}$ $\frac{1}{32}$ | ·37 „ $\frac{3}{8}$ |
| $2\frac{5}{8}$ | ·58 „ $\frac{9}{16}$ $\frac{1}{64}$ | ·18 „ $\frac{3}{16}$ | $5\frac{1}{2}$ | 1·21 „ $1\frac{3}{16}$ $\frac{1}{64}$ | ·38 „ $\frac{3}{8}$ |
| $2\frac{3}{4}$ | ·60 „ $\frac{9}{16}$ $\frac{1}{32}$ | ·19 „ $\frac{3}{16}$ | $5\frac{3}{4}$ | 1·26 „ $1\frac{1}{4}$ | ·40 „ $\frac{3}{8}$ $\frac{1}{32}$ |
| $2\frac{7}{8}$ | ·63 „ $\frac{10}{16}$ | ·20 „ $\frac{3}{16}$ $\frac{1}{64}$ | 6 | 1·32 „ $1\frac{5}{16}$ | ·42 „ $\frac{3}{8}$ $\frac{3}{64}$ |
| 3 | ·66 „ $\frac{10}{16}$ $\frac{1}{32}$ | ·21 „ $\frac{3}{16}$ $\frac{1}{64}$ | $6\frac{3}{4}$ | 1·50 „ $1\frac{1}{2}$ | ·47 „ $\frac{7}{16}$ $\frac{1}{32}$ |

In the Table 279, following, is shown the relative distribution for a slide-valve of the proportions assumed in rule 4, above; with admissions varied from 73·5 per cent. (say 75) to 12 per cent., for the corresponding travels given in the last two columns.

### TABLE 279.—DISTRIBUTION FOR VARIOUS TRAVELS OF A VALVE OF STANDARD PROPORTIONS.

| Steam Cut-off. | Steam Exhausted. | Point of Compression. | Point of Admission. | Travel of the Valve. Lap 1 Inch. Lead $\frac{5}{16}$ Inch. | |
|---|---|---|---|---|---|
| Per Cent. | Per Cent. | Per Cent. | Per Cent. | Inches. | Per Cent. of Maximum Travel. |
| 75 | 91 | 9 | ·62 | $4\frac{1}{2}$ | 100 |
| 60 | 86 | 14 | 1·10 | $3\frac{3}{4}$ | 83 |
| 50 | 80 | 20 | 1·90 | $3\frac{3}{8}$ | 75 |
| 40 | 75 | 25 | 2·50 | $3\frac{1}{32}$ | 67 |
| 30 | 68 | 32 | 4·35 | $2\frac{13}{16}$ | 62 |
| 20 | 57 | 43 | 7·60 | $2\frac{11}{16}$ | 60 |
| 12 | 50 | 50 | 12·25 | $2\frac{5}{8}$ | 58·3 |

## TABLE 280.—PERIODS OF ADMISSION FOR VARYING TRAVELS AND LAPS OF THE SLIDE-VALVE.

Lead $\frac{5}{16}$ inch.

| Travel. | Lap in Inches. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | $\frac{1}{2}$ | $\frac{5}{8}$ | $\frac{3}{4}$ | $\frac{7}{8}$ | 1 | $1\frac{1}{8}$ | $1\frac{1}{4}$ | $1\frac{3}{8}$ | $1\frac{1}{2}$ |
| | Periods of Admission in Percentages of Stroke. | | | | | | | | |
| Inches. | % | % | % | % | % | % | % | % | % |
| $1\frac{5}{8}$ | 19 | ... | ... | ... | ... | ... | ... | ... | ... |
| $1\frac{3}{4}$ | 39 | ... | ... | ... | ... | ... | ... | ... | ... |
| $1\frac{7}{8}$ | 47 | 17 | ... | ... | ... | ... | ... | ... | ... |
| 2 | 55 | 34 | ... | ... | ... | ... | ... | ... | ... |
| $2\frac{1}{8}$ | 61 | 42 | 14 | ... | ... | ... | ... | ... | ... |
| $2\frac{1}{4}$ | 65 | 50 | 30 | ... | ... | ... | ... | ... | ... |
| $2\frac{3}{8}$ | 68 | 55 | 38 | 13 | ... | ... | ... | ... | ... |
| $2\frac{1}{2}$ | 71 | 59 | 45 | 27 | ... | ... | ... | ... | ... |
| $2\frac{5}{8}$ | 74 | 63 | 49 | 36 | 12 | ... | ... | ... | ... |
| $2\frac{3}{4}$ | 76 | 67 | 56 | 43 | 26 | ... | ... | ... | ... |
| $2\frac{7}{8}$ | 78 | 70 | 59 | 47 | 32 | 11 | ... | ... | ... |
| 3 | 80 | 73 | 62 | 50 | 38 | 23 | ... | ... | ... |
| $3\frac{1}{8}$ | 81 | 74 | 65 | 55 | 44 | 30 | 10 | ... | ... |
| $3\frac{1}{4}$ | 83 | 76 | 68 | 59 | 48 | 34 | 22 | ... | ... |
| $3\frac{3}{8}$ | 84 | 78 | 71 | 62 | 51 | 40 | 29 | 9 | ... |
| $3\frac{1}{2}$ | 85 | 80 | 73 | 64 | 53 | 45 | 34 | 20 | ... |
| $3\frac{5}{8}$ | 86 | 81 | 75 | 66 | 57 | 49 | 38 | 26 | 9 |
| $3\frac{3}{4}$ | 87 | 82 | 76 | 68 | 60 | 52 | 42 | 32 | 19 |
| $3\frac{7}{8}$ | 87 | 83 | 78 | 70 | 63 | 55 | 46 | 36 | 25 |
| 4 | 88 | 84 | 79 | 72 | 66 | 58 | 49 | 40 | 29 |
| $4\frac{1}{4}$ | 89 | 86 | 81 | 76 | 70 | 63 | 56 | 47 | 37 |
| $4\frac{1}{2}$ | 90 | 87 | 83 | 79 | 73 | 67 | 61 | 54 | 45 |
| $4\frac{3}{4}$ | 92 | 89 | 85 | 81 | 76 | 70 | 65 | 58 | 51 |
| 5 | 93 | 90 | 87 | 83 | 78 | 73 | 67 | 62 | 56 |
| $5\frac{1}{2}$ | 94 | 92 | 89 | 86 | 82 | 78 | 73 | 68 | 63 |
| 6 | 95 | 93 | 91 | 88 | 85 | 82 | 78 | 74 | 69 |

TABLE 281.—PERIODS OF ADMISSION, OR POINTS OF CUT-OFF, FOR GIVEN TRAVELS AND LAPS OF SLIDE-VALVES.

| Travel of Valve. | Lead of Value. | Periods of Admission, or Points of Cut-off, for the following Laps of Valve, in Inches, in Percentages of Stroke. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2 | $1\frac{3}{4}$ | $1\frac{1}{2}$ | $1\frac{1}{4}$ | 1 | $\frac{7}{8}$ | $\frac{3}{4}$ | $\frac{5}{8}$ | $\frac{1}{2}$ | $\frac{3}{8}$ |
| Inches. | Inch. | % | % | % | % | % | % | % | % | % | % |
| 12 | $\frac{1}{4}$ | 88 | 90 | 93 | 95 | 96 | 97 | 98 | 98 | 99 | 99 |
| 10 | $\frac{1}{4}$ | 82 | 87 | 89 | 92 | 95 | 96 | 97 | 98 | 98 | 99 |
| 8 | $\frac{1}{4}$ | 72 | 78 | 84 | 88 | 92 | 94 | 95 | 96 | 98 | 98 |
| 6 | $\frac{1}{4}$ | 50 | 62 | 71 | 79 | 86 | 89 | 91 | 94 | 96 | 97 |
| $5\frac{1}{2}$ | $\frac{1}{8}$ | 43 | 56 | 68 | 77 | 85 | 88 | 91 | 94 | 96 | 97 |
| 5 | $\frac{1}{8}$ | 32 | 47 | 61 | 72 | 82 | 86 | 89 | 92 | 95 | 97 |
| $4\frac{1}{2}$ | $\frac{1}{8}$ | 14 | 35 | 51 | 66 | 78 | 83 | 87 | 90 | 94 | 96 |
| 4 | $\frac{1}{8}$ | ... | 17 | 39 | 57 | 72 | 78 | 83 | 88 | 92 | 95 |
| $3\frac{1}{2}$ | $\frac{1}{8}$ | ... | ... | 20 | 44 | 63 | 71 | 79 | 84 | 90 | 94 |
| 3 | $\frac{1}{8}$ | ... | ... | ... | 23 | 50 | 61 | 71 | 79 | 86 | 91 |
| $2\frac{1}{2}$ | $\frac{1}{8}$ | ... | ... | ... | ... | 27 | 43 | 57 | 70 | 80 | 88 |
| 2 | $\frac{1}{8}$ | ... | ... | ... | ... | ... | ... | 33 | 52 | 70 | 81 |

**Woolf Engine:—Continuous Expansion in two Cylinders.**

The total work for one stroke of the two pistons, may be calculated by the formula (5), page 514, for the work of a single cylinder.

**Receiver Engine:—Successive Expansions in two Cylinders.**

The total work for one stroke of the two pistons, may be calculated by the formula:—

$$w = a\,P\left[l'(1 \times \text{hyp. log. } R'') - e\,\left(1 \times \frac{r-1}{R'}\right)\right] \quad . \quad . \ (12)$$

In the construction of the foregoing formulæ, it is assumed that the line of pressure during admission of steam is straight and parallel to the datum-line; that the expansion curves are hyperbolic to the end of the strokes; that the exhaust is open to the end of the return stroke of the second piston; and that there is no back pressure on it.

The work of back pressure is most directly measured from the indicator diagram, in which the other modifications of performance due to compression, and wiredrawing may also be measured.

RULE.—*To find the indicator horse-power of a single-cylinder steam engine, from the indicator diagram.* Multiply the area of the piston in square inches by the effective mean pressure on the piston in pounds per square inch, and by twice the length of the stroke, and by the number of revolutions per minute; and divide the product by 33,000. The quotient is the indicator horse-power.

For compound and multiple-expansion engines, the indicator power in each cylinder is calculated separately; and the sum of the powers thus obtained is the total indicator horse-power. When strokes of the pistons are equal, and if the horse-powers of the cylinders are not required separately, it will suffice to multiply the area of each piston by the effective mean pressure; and to complete the calculation with the sum of these products.

The best performance of steam engines under various conditions, may be accepted approximately to be as follows:—

*Single Cylinders, not steam-jacketed, non-condensing.*—Steam cut off at one-third of the stroke, and consumed at the rate of 26 pounds per indicator horse-power per hour; the effective pressure during admission being 60 lbs. per square inch.

*Single Cylinders, using superheated steam, non-condensing.*—With 80 lbs. effective pressure of steam during admission, cutting off at one-fifth; 18½ pounds of steam consumed per indicator horse-power per hour. For a lower effective mean pressure of 34 lbs. per square inch, cutting off at about 30 per cent. with 130 degrees of superheat, about 30½ pounds of steam are consumed per indicator horse-power per hour.

*Single Cylinders, steam-jacketed, non-condensing.*—With 75 lbs. effective pressure during admission, cutting off at one-fifth, 25 pounds of steam are consumed per indicator horse-power per hour.

*Single Cylinders, with superheated steam, condensing.*—With 65 lbs. effective pressure during admission, and 150 degrees of superheat, cutting off at 22½ per cent. of the stroke, 15½ pounds of steam are consumed per indicator horse-power per hour.

*Single Cylinders, not steam-jacketed, condensing.*—The economical results are affected by the length of the stroke relatively to the diameter. In strokes considerably longer than the diameters, an admission of from 15 per cent. to 20 per cent. is most efficient for economy. With initial steam of 80 lbs. total pressure per square inch, approximately 20 pounds of steam are consumed per indicator horse-power per hour.

For short-stroke cylinders—having strokes considerably shorter than two diameters—with initial steam of 73 lbs. total pressure, approximately 25 pounds of steam are consumed per horse-power.

*Single Cylinders, steam-jacketed, condensing.*—The period of admission most favourable for economy, is from 15 per cent. to 25 per cent. of the stroke. For thoroughly steam-jacketed cylinders, of long strokes, the longer periods of admission are preferable; and for those of short strokes, the shorter periods. For cylinders jacketed only at the sides or barrel, the longer ranges are preferable. With thoroughly steam-jacketed cylinders of long stroke, and steam of 80 lbs. total initial pressure, about 18½ pounds of steam are consumed per indicator horse-power per hour; and for cylinders of short stroke, 21 pounds.

## Woolf Compound Steam Engines.

Proportionally long strokes, compared with proportionally short strokes, are conducive to economy. With a stroke of five diameters, and a total initial pressure of 100 lbs. per square inch, and worked with 12 actual expansions, the work is done for about 14 pounds of steam per indicator horse-power per hour. With a stroke equal to twice the diameter, 17½ pounds are consumed.

## Receiver Compound Steam Engines.

With a stroke equal to from two to three diameters of the first cylinder, for a total initial pressure of from 80 lbs. to 90 lbs. per square inch, cutting off at one-fifth, and ten actual expansions, with thorough jacketing and intermediate heating of steam, the work may be done with a consumption of 15 pounds of steam per indicator horse-power per hour. With shorter strokes—from 1⅛ to 1½ diameters—18½ pounds are consumed. Without steam-jacketing, the consumption of steam is from 2 pounds to 3 pounds more.

## Capacity-ratio of Multiple-Expansion Cylinders.

For speed of piston of from 750 feet to 1000 feet per minute, the capacity-ratios of triple-expansion steam engines, given in the following Table, are recommended. They are based upon a wide range of practice. The terminal absolute pressure of steam in the third cylinder, is supposed to be about 10 lbs. per square inch.

TABLE 282.—TRIPLE-EXPANSION STEAM ENGINES:—CAPACITY-RATIOS OF CYLINDERS RECOMMENDED.

(Jay M. Whitham.)

| Gauge Pressure per Square Inch in the Boiler. | Capacity-Ratios of Cylinders. | | |
|---|---|---|---|
| | 1st (Small). | 2nd (Intermediate). | 3rd (Large). |
| Pounds. | Ratio. | Ratio. | Ratio. |
| 130 | 1 | 2·25 | 5·00 |
| 140 | 1 | 2·40 | 5·85 |
| 150 | 1 | 2·55 | 6·90 |
| 160 | 1 | 2·70 | 7·25 |
| 170 and upwards | Quadruple expansion to be adopted. | | |

For quadruple expansion, with steam of, say, 180 lbs. per square inch, capacity-ratios of four cylinders, taken as 1, 2, 4, 8, are very suitable.

**Efficiency and Frictional Resistance of Steam Engines.**

The frictional resistance of steam engines varies inversely as their leading dimensions. A direct-action engine having a 4-inch cylinder, yielded at the main shaft only 43 per cent. of the indicator power, with a frictional resistance of 57 per cent.

Eight horse-power portable engines, having 9-inch cylinders, yield from 78 per cent. to 87 per cent., with from 13 per cent. to 22 per cent. of resistance.

Corliss engines having 18-inch and 24-inch cylinders, yield about 90 per cent. of the indicator power at the main shaft; with about 10 per cent. of resistance.

Compound engines having first cylinders of from 12 inches to 21 inches in diameter, with or without a beam, yield from 80 per cent. to 89 per cent. of the indicator power.

Rotative pumping steam engines yield from 80 per cent. to 86 per cent. of duty; Worthington's large pumping engines for waterworks, yield 91 per cent. So also do Cornish pumping engines.

From the results of experiments made by Dr. Thurston, on the distribution of friction in direct-acting non-condensing steam engines having balanced valves, it appears that from 40 per cent. to 47 per cent. of the resistance arises at the main bearings; about 33 per cent. at the piston and its rod, 7 per cent. at the crank-pin, $5\frac{1}{2}$ per cent. at the crosshead and

gudgeon, 2½ per cent. at the valve and its rod, 5¼ per cent. at the excentric-strap. An unbalanced valve absorbed 26½ per cent. of the whole resistance. In a condensing engine, the air-pump caused 12 per cent. of the resistance.

The frictional resistance of a steam engine increases very slowly with the load. In some cases, the load may be doubled whilst the resistance is increased by only one-fifth.

### Lancashire Steam Boiler—Standard Data.

*Boiler of Wrought-iron.*—Shell 7 feet in diameter, 27 feet long; two furnace-tubes, 2 feet 9 inches in diameter. Shell plates $\frac{7}{16}$ inch thick for a working steam pressure of 75 lbs. per square inch; $\frac{9}{16}$ inch thick for 100 lbs. pressure. Plates of furnace-tubes, $\frac{3}{8}$ inch and $\frac{7}{16}$ inch respectively.

Fire-grates 6 feet long; fire-bars $\frac{3}{4}$ inch thick; air-spaces between fire-bars, $\frac{3}{8}$ inch wide.

Height of flue-way over each bridge, 14 inches; side flues 6 inches wide at the top; width of bottom flue equal to the semi-diameter of the boiler, or 3½ feet. The draught passes from the furnace-tubes to the bottom flue, thence by the sides to the back.

The grate-area is 16½ square feet for one furnace, or 33 square feet for both furnaces. The air-space through each grate is 5½ square feet, or one-third of the grate-area.

The flue-way over each bridge is 1·88 square feet, or 11½ per cent. of the grate-area—about $\frac{1}{8}$th.

Each furnace-tube has 5·94 square feet of sectional area beyond the bridge = nearly one-third of the grate-area.

The bottom flue has 7 square feet of sectional area, or fully one-fifth of the whole grate-area.

The side flues have a united area of 12½ square feet, or nearly two-fifths of the whole grate-area.

The weight of the boiler is about 12 tons; with fittings, 15½ tons. The cost is about £425, or about £27 8*s*. per ton, or £16 per lineal foot.

The heating surface is 850 square feet, or 26 times the grate-area. The heating surface is augmented by feed-water heaters, occasionally to the extent of three-fourths. In such a boiler, from 15 tons to 20 tons of coal may, without undue stress, be consumed per week of 60 hours, or from 5 cwt. to 6¼ cwt. per hour, or from 17 lbs. to 23 lbs. per square foot of fire-grate per hour. At the rate of 8 pounds of water per pound of coal, this corresponds to an evaporation of from 70 to 90 cubic feet of water per hour.

In the best practice, iron boiler-plates have a tensile strength of from 24 to 25 tons per square inch, with an elongati-

from 10 per cent. to 15 per cent.; and steel boiler-plates from 27 to 32 tons, with 30 per cent. of elongation. For a 7-feet boiler, at 80 lbs. pressure, $\frac{1}{2}$ inch iron plates, or $\frac{3}{8}$ inch steel plates are used.

The nominal horse-power of Lancashire and Cornish boilers, is reckoned at the rate of 6 square feet of the combined horizontal area of the shell and the flues. The horizontal area is the product of the length by the sum of the diameters of the shell and flues. Thus, a Lancashire boiler 27 feet long, 7 feet in diameter, with two furnace-tubes $2\frac{3}{4}$ feet in diameter, has a horizontal area of $(27 \times (7 + 2\frac{3}{4} + 2\frac{3}{4})) = 337\frac{1}{2}$ square feet; divided by 6, it gives 56 nominal horse-power. The grate-area is ·60 square foot—a little more than half a foot—per horse-power; and there is 15 square feet of heating surface per horse-power.

### Factory Chimneys.

The proportions of chimneys vary very much with relation to the requirements. The quantity of good coal that may be consumed per hour with a chimney of a given height above the level of the fire-grates, and a given top-sectional area, and a temperature in the chimney equal to or near to 600° F., under easy conditions, is expressed by the formula :—

$$C = 16A\sqrt{H} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (13)$$

C = coal consumed per hour, in pounds.
A = sectional area of chimney at top, in square feet.
H = height of chimney above the level of the grates, in feet.
G = total area of fire-grates, in square feet.

When the top diameter of the chimney is one-thirtieth of the height—a good proportion—the formula becomes,—

$$C = \cdot014\ H^{2\cdot5} \quad . \quad . \quad . \quad . \quad . \quad (14)$$

$$C = \cdot014\ H^2\sqrt{H} \quad . \quad . \quad . \quad . \quad . \quad . \quad (15)$$

And the total grate-area, allowing a consumption of 15 pounds of coal per square foot per hour, is,—

$$G = \frac{H^2\sqrt{H}}{1071} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (16)$$

$$\text{or } G = \frac{H^{2\cdot5}}{1071} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (17)$$

The height of chimney for a given total grate-area, the diameter at the top being equal to one-thirtieth of the height, is,—

$$H = 16\cdot3^{2\cdot5}\sqrt{G} \quad . \quad . \quad . \quad . \quad . \quad (18)$$

The side of a square chimney equal in sectional area to a given round chimney, is equal to the product of the diameter by ·886; and the equivalent fraction of the height for the side of a square chimney is one thirty-fourth.

Conversely, the diameter of a round chimney equal in sectional area to a given square chimney, is equal to the product of the side of the square by 1·13.

In Table 283, are given the quantity of coals that may be consumed per hour, at the assumed rate of 15 pounds per square foot per hour, and the corresponding total area of fire-grate, for chimneys of various heights, and corresponding diameters one-thirtieth of the respective heights.

TABLE 283.—FACTORY CHIMNEYS.—COAL CONSUMPTION.

| Chimney. Height. | Chimney. Diameter. | | Coal Consumable per Hour. | Grate Area. | Chimney. Height. | Chimney. Diameter. | | Coal Consumable per Hour. | Grate Area. |
|---|---|---|---|---|---|---|---|---|---|
| Feet. | Ft. | Ins. | Pounds. | Sq. Ft. | Feet. | Ft. | Ins. | Pounds. | Sq. Ft. |
| 40 | 1 | 4 | 142 | 9·5 | 110 | 3 | 8 | 1777 | 118·4 |
| 50 | 1 | 8 | 248 | 16·5 | 120 | 4 | 0 | 2208 | 147·2 |
| 60 | 2 | 0 | 390 | 26·0 | 135 | 4 | 6 | 2964 | 197·6 |
| 70 | 2 | 4 | 574 | 38·3 | 150 | 5 | 0 | 3858 | 257·2 |
| 80 | 2 | 8 | 801 | 53·4 | 165 | 5 | 6 | 4896 | 326·4 |
| 90 | 3 | 0 | 1076 | 71·7 | 180 | 6 | 0 | 6086 | 405·7 |
| 100 | 3 | 4 | 1394 | 93·0 | 200 | 6 | 8 | 7920 | 526·6 |

TABLE 284.—HORSE-POWER IN VARIOUS COUNTRIES IN FOOT-POUNDS PER SECOND.

("Steam.")

| Country. | Kilogrameters per sec. | Baden per sec. | Saxony per sec. | Würtemberg per sec. |
|---|---|---|---|---|
| | | Foot-lbs. | Foot-lbs. | Foot-lbs. |
| France and Baden | **75** | **500** | 529·68 | 521·58 |
| Saxony . . . | 75·045 | 500·30 | **530** | 523·89 |
| Würtemberg . . | 75·240 | 501·36 | 531·12 | **525** |
| Prussia . . . | 75·325 | 502·17 | 531·97 | 525·85 |
| Hanover . . . | 75·361 | 502·41 | 532·23 | 526·10 |
| England . . | 76·041 | 506·94 | 537·03 | 530·84 |
| Austria . . . | 76·119 | 507·46 | 537·58 | 531·39 |

TABLE 284.—HORSE-POWER IN VARIOUS COUNTRIES (*con.*).

| Country. | Prussian per sec. | Hanoverian per sec. | English per sec. | Austrian per sec. |
|---|---|---|---|---|
| | Foot-lbs. | Foot-lbs. | Foot-lbs. | Foot-lbs. |
| France and Baden | 477·93 | 513·53 | 542·47 | 423·68 |
| Saxony . . | 478·22 | 513·84 | 542·80 | 423·93 |
| Würtemberg . . | 479·23 | 514·92 | 543·95 | 424·83 |
| Prussia . . | **480** | 515·75 | 544·82 | 425·51 |
| Hanover . . . | 480·23 | **516** | 545·08 | 425·72 |
| England . . | 484·56 | 520·65 | **550** | 429·56 |
| Austria . . . | 485·06 | 521·19 | 550·57 | **430** |

TABLE 285.—ECONOMY OF FUEL BY HEATING THE FEED-WATER.

(For Steam of 60 lbs. per square inch Working Pressure.)

| Initial Temperature of Water. | Final Temperature of Feed-Water (Fahrenheit). 120° | 140° | 160° | 180° | 200° | 250° | 300° |
|---|---|---|---|---|---|---|---|
| ° Fahr. | % | % | % | % | % | % | % |
| 32 | 7·50 | 9·20 | 10·90 | 12·36 | 14·30 | 19·03 | 22·90 |
| 35 | 7·25 | 8·96 | 10·66 | 12·09 | 14·09 | 18·34 | 22·60 |
| 40 | 6·85 | 8·57 | 10·28 | 12·00 | 13·71 | 17·99 | 22·27 |
| 45 | 6·45 | 8·17 | 9·90 | 11·61 | 13·34 | 17·64 | 21·94 |
| 50 | 6·05 | 7·71 | 9·50 | 11·23 | 13·00 | 17·28 | 21·61 |
| 55 | 5·64 | 7·37 | 9·06 | 10·85 | 12·60 | 16·93 | 21·27 |
| 60 | 5·23 | 6·97 | 8·72 | 10·46 | 12·20 | 16·58 | 20·92 |
| 65 | 4·82 | 6·56 | 8·32 | 10·07 | 11·82 | 16·20 | 20·58 |
| 70 | 4·40 | 6·15 | 7·91 | 9·08 | 11·43 | 15·83 | 20·23 |
| 75 | 3·98 | 5·74 | 7·50 | 9·28 | 11·04 | 15·46 | 19·88 |
| 80 | 3·55 | 5·32 | 7·09 | 8·87 | 10·65 | 15·08 | 19·52 |
| 85 | 3·12 | 4·90 | 6·63 | 8·46 | 10·25 | 14·70 | 19·17 |
| 90 | 2·68 | 4·47 | 6·26 | 8·06 | 9·85 | 14·32 | 18·81 |
| 95 | 2·24 | 4·04 | 5·84 | 7·65 | 9·44 | 13·94 | 18·44 |
| 100 | 1·80 | 3·61 | 5·42 | 7·23 | 9·03 | 13·55 | 18·07 |
| 110 | ·90 | 2·73 | 4·55 | 3·38 | 8·20 | 12·76 | 17·28 |
| 120 | 0 | 1·84 | 3·67 | 5·52 | 7·36 | 11·95 | 16·49 |
| 130 | ... | ·92 | 2·77 | 4·64 | 6·99 | 11·14 | 15·24 |
| 140 | ... | 0 | 1·87 | 3·75 | 5·62 | 10·31 | 14·99 |
| 150 | ... | ... | ·94 | 2·83 | 4·72 | 9·46 | 14·18 |
| 160 | ... | ... | 0 | 1·91 | 3·82 | 8·59 | 13·37 |
| 170 | ... | ... | ... | ·96 | 2·89 | 7·71 | 12·54 |
| 180 | ... | ... | ... | 0 | 1·96 | 6·81 | 11·70 |
| 190 | ... | ... | ... | ... | ·90 | 5·90 | 10·82 |
| 200 | ... | ... | ... | ... | 0 | 4·85 | 9·93 |

TABLE 286.—RELATIVE ECONOMY OF FEED-APPARATUS. (Jacobus.)

| Feed Water: how Supplied. | Relative Consumption of Coal. | Relative Economy Effected. |
|---|---|---|
| Direct-acting pump, feeding water at 60°, without a heater . . | 1·000 | 0·0 |
| Injector feeding water at 150° without a heater . . . . | ·985 | 1·5 per cent. |
| Injector feeding through a heater in which the water is heated from 150° to 200° . . . | ·938 | 6·2 ,, |
| Direct-acting pump, feeding water through a heater, in which it is heated from 60° to 200° . . . | ·879 | 12·1 ,, |
| Geared pump, run from the engine, feeding water through a heater, in which it is heated from 60° to 200° . . . . . | ·868 | 13·2 ,, |

TABLE 287.—WEIGHT OF SEDIMENT COLLECTED IN A STEAM-BOILER, FROM HARD WATER, EVAPORATED AT THE RATE OF 1000 GALLONS PER DAY.

| Solid Matter per Gallon Evaporated. | Solid Matter Collected per Day, from 1000 Gallons of Water Evaporated. | | Solid Matter Collected per Week of Six Days, from 6000 Gallons of Water Evaporated. | | Solid Matter per Gallon Evaporated. | Solid Matter Collected per Day, from 1000 Gallons of Water Evaporated. | | Solid Matter Collected per Week of Six Days, from 6000 Gallons of Water Evaporated. | |
|---|---|---|---|---|---|---|---|---|---|
| Grains. | Lbs. | Ozs. | Lbs. | Ozs. | Grains. | Lbs. | Ozs. | Lbs. | Ozs. |
| 1 | 0 | 2·3 | 0 | 13·7 | 15 | 2 | 2·3 | 12 | 13·7 |
| 2 | 0 | 4·6 | 1 | 11·4 | 20 | 2 | 13·7 | 17 | 2·3 |
| 3 | 0 | 6·9 | 2 | 9·1 | 25 | 3 | 9·1 | 21 | 6·9 |
| 4 | 0 | 9·1 | 3 | 6·9 | 30 | 4 | 4·6 | 25 | 11·4 |
| 5 | 0 | 11·4 | 4 | 4·6 | 35 | 5 | 0 | 30 | 0 |
| 6 | 0 | 13·7 | 5 | 2·3 | 40 | 5 | 11·4 | 34 | 4·6 |
| 7 | 1 | 0 | 6 | 0 | 45 | 6 | 6·9 | 38 | 9·1 |
| 8 | 1 | 2·3 | 6 | 13·7 | 50 | 7 | 2·3 | 42 | 13·7 |
| 9 | 1 | 4·6 | 7 | 11·4 | 55 | 7 | 13·7 | 47 | 2·3 |
| 10 | 1 | 6·9 | 8 | 9·1 | | | | | |

TABLE 288.—MULTIPLIERS FOR FINDING THE EQUIVALENT FOR GIVEN PRESSURES OF STEAM AND

| Temperature of Feed Water. | Boiler Pressures in Pounds per | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 |
| ° Fahr. | | | | | | | | | | |
| 32 | 1·187 | 1·192 | 1·195 | 1·199 | 1·201 | 1·204 | 1·206 | 1·209 | 1·211 | 1·212 |
| 35 | 1·184 | 1·189 | 1·192 | 1·196 | 1·198 | 1·201 | 1·203 | 1·206 | 1·208 | 1·209 |
| 40 | 1·179 | 1·184 | 1·187 | 1·191 | 1·193 | 1·196 | 1·198 | 1·201 | 1·203 | 1·204 |
| 45 | 1·173 | 1·178 | 1·181 | 1·185 | 1·187 | 1·190 | 1·192 | 1·195 | 1·197 | 1·198 |
| 50 | 1·168 | 1·173 | 1·177 | 1·180 | 1·182 | 1·185 | 1·187 | 1·190 | 1·192 | 1·193 |
| 55 | 1·163 | 1·168 | 1·171 | 1·175 | 1·177 | 1·180 | 1·182 | 1·185 | 1·187 | 1·188 |
| 60 | 1·158 | 1·163 | 1·166 | 1·170 | 1·172 | 1·175 | 1·177 | 1·180 | 1·182 | 1·183 |
| 65 | 1·153 | 1·158 | 1·161 | 1·165 | 1·167 | 1·170 | 1·172 | 1·175 | 1·177 | 1·178 |
| 70 | 1·148 | 1·153 | 1·156 | 1·160 | 1·162 | 1·165 | 1·167 | 1·170 | 1·172 | 1·173 |
| 75 | 1·143 | 1·148 | 1·151 | 1·155 | 1·157 | 1·160 | 1·162 | 1·165 | 1·167 | 1·168 |
| 80 | 1·137 | 1·143 | 1·146 | 1·149 | 1·151 | 1·154 | 1·156 | 1·159 | 1·161 | 1·162 |
| 85 | 1·132 | 1·137 | 1·140 | 1·144 | 1·146 | 1·149 | 1·151 | 1·154 | 1·156 | 1·157 |
| 90 | 1·127 | 1·132 | 1·135 | 1·139 | 1·141 | 1·144 | 1·146 | 1·149 | 1·151 | 1·152 |
| 95 | 1·122 | 1·127 | 1·130 | 1·134 | 1·136 | 1·139 | 1·141 | 1·144 | 1·146 | 1·147 |
| 100 | 1·117 | 1·122 | 1·125 | 1·129 | 1·131 | 1·134 | 1·136 | 1·139 | 1·141 | 1·142 |
| 105 | 1·111 | 1·117 | 1·120 | 1·123 | 1·125 | 1·128 | 1·130 | 1·133 | 1·135 | 1·136 |
| 110 | 1·106 | 1·111 | 1·114 | 1·118 | 1·120 | 1·123 | 1·125 | 1·128 | 1·130 | 1·131 |
| 115 | 1·101 | 1·106 | 1·109 | 1·113 | 1·115 | 1·118 | 1·120 | 1·123 | 1·125 | 1·126 |
| 120 | 1·096 | 1·101 | 1·104 | 1·108 | 1·110 | 1·113 | 1·115 | 1·118 | 1·120 | 1·121 |
| 125 | 1·091 | 1·096 | 1·099 | 1·103 | 1·105 | 1·108 | 1·110 | 1·113 | 1·115 | 1·116 |
| 130 | 1·085 | 1·091 | 1·094 | 1·097 | 1·099 | 1·102 | 1·104 | 1·107 | 1·109 | 1·110 |
| 135 | 1·080 | 1·085 | 1·088 | 1·092 | 1·094 | 1·097 | 1·099 | 1·102 | 1·104 | 1·105 |
| 140 | 1·075 | 1·080 | 1·083 | 1·087 | 1·089 | 1·092 | 1·094 | 1·097 | 1·099 | 1·100 |
| 145 | 1·070 | 1·075 | 1·078 | 1·082 | 1·084 | 1·087 | 1·089 | 1·092 | 1·094 | 1·095 |
| 150 | 1·065 | 1·070 | 1·073 | 1·077 | 1·079 | 1·082 | 1·084 | 1·087 | 1·089 | 1·090 |
| 155 | 1·059 | 1·065 | 1·068 | 1·071 | 1·073 | 1·076 | 1·078 | 1·081 | 1·083 | 1·084 |
| 160 | 1·054 | 1·059 | 1·062 | 1·066 | 1·068 | 1·071 | 1·073 | 1·076 | 1·078 | 1·079 |
| 165 | 1·049 | 1·054 | 1·057 | 1·061 | 1·063 | 1·066 | 1·068 | 1·071 | 1·073 | 1·074 |
| 170 | 1·044 | 1·049 | 1·052 | 1·056 | 1·058 | 1·061 | 1·063 | 1·066 | 1·068 | 1·069 |
| 175 | 1·039 | 1·044 | 1·047 | 1·051 | 1·053 | 1·056 | 1·058 | 1·061 | 1·063 | 1·064 |
| 180 | 1·033 | 1·039 | 1·042 | 1·045 | 1·047 | 1·050 | 1·052 | 1·055 | 1·057 | 1·058 |
| 185 | 1·028 | 1·033 | 1·036 | 1·040 | 1·042 | 1·045 | 1·047 | 1·050 | 1·052 | 1·053 |
| 190 | 1·023 | 1·028 | 1·031 | 1·035 | 1·037 | 1·040 | 1·042 | 1·045 | 1·047 | 1·048 |
| 195 | 1·018 | 1·023 | 1·025 | 1·030 | 1·032 | 1·035 | 1·057 | 1·040 | 1·042 | 1·043 |
| 200 | 1·013 | 1·018 | 1·021 | 1·025 | 1·027 | 1·030 | 1·032 | 1·035 | 1·037 | 1·038 |
| 205 | 1·008 | 1·013 | 1·015 | 1·020 | 1·022 | 1·025 | 1·027 | 1·030 | 1·032 | 1·033 |
| 210 | 1·008 | 1·008 | 1·011 | 1·015 | 1·017 | 1·020 | 1·022 | 1·025 | 1·027 | 1·028 |
| 212 | 1·002 | 1·002 | ... | ... | ... | ... | ... | ... | ... | ... |

RATE OF EVAPORATION OF WATER FROM AND AT 212° F., TEMPERATURES OF FEED-WATER.

Square Inch above the Atmosphere.

| 50 | 60 | 70 | 80 | 90 | 100 | 120 | 140 | 160 | 180 | 200 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1·214 | 1·217 | 1·219 | 1·222 | 1·224 | 1·227 | 1·231 | 1·234 | 1·237 | 1·239 | 1·241 |
| 1·211 | 1·214 | 1·216 | 1·219 | 1·221 | 1·224 | 1·228 | 1·231 | 1·234 | 1·236 | 1·238 |
| 1·206 | 1·209 | 1·211 | 1·214 | 1·216 | 1·219 | 1·223 | 1·226 | 1·229 | 1·231 | 1·233 |
| 1·200 | 1·203 | 1·205 | 1·208 | 1·210 | 1·213 | 1·217 | 1·220 | 1·223 | 1·225 | 1·227 |
| 1·195 | 1·198 | 1·200 | 1·203 | 1·205 | 1·208 | 1·212 | 1·215 | 1·218 | 1·220 | 1·222 |
| 1·190 | 1·193 | 1·195 | 1·198 | 1·200 | 1·203 | 1·207 | 1·210 | 1·213 | 1·215 | 1·217 |
| 1·185 | 1·188 | 1·190 | 1·193 | 1·195 | 1·198 | 1·202 | 1·205 | 1·208 | 1·210 | 1·212 |
| 1·180 | 1·183 | 1·185 | 1·188 | 1·190 | 1·193 | 1·197 | 1·200 | 1·203 | 1·205 | 1·207 |
| 1·175 | 1·178 | 1·180 | 1·183 | 1·185 | 1·188 | 1·192 | 1·195 | 1·198 | 1·200 | 1·202 |
| 1·170 | 1·173 | 1·175 | 1·178 | 1·180 | 1·183 | 1·187 | 1·190 | 1·193 | 1·195 | 1·197 |
| 1·164 | 1·167 | 1·169 | 1·172 | 1·174 | 1·177 | 1·181 | 1·184 | 1·187 | 1·189 | 1·191 |
| 1·159 | 1·162 | 1·164 | 1·167 | 1·169 | 1·172 | 1·176 | 1·179 | 1·182 | 1·184 | 1·186 |
| 1·154 | 1·157 | 1·159 | 1·162 | 1·164 | 1·167 | 1·171 | 1·174 | 1·177 | 1·179 | 1·181 |
| 1·149 | 1·152 | 1·154 | 1·157 | 1·159 | 1·162 | 1·166 | 1·169 | 1·172 | 1·174 | 1·176 |
| 1·144 | 1·147 | 1·149 | 1·152 | 1·154 | 1·157 | 1·161 | 1·164 | 1·167 | 1·169 | 1·171 |
| 1·133 | 1·141 | 1·143 | 1·146 | 1·148 | 1·151 | 1·155 | 1·158 | 1·161 | 1·163 | 1·165 |
| 1·133 | 1·136 | 1·138 | 1·141 | 1·143 | 1·146 | 1·150 | 1·153 | 1·156 | 1·158 | 1·160 |
| 1·128 | 1·131 | 1·133 | 1·136 | 1·138 | 1·141 | 1·145 | 1·148 | 1·151 | 1·153 | 1·155 |
| 1·123 | 1·126 | 1·128 | 1·131 | 1·133 | 1·136 | 1·140 | 1·143 | 1·146 | 1·148 | 1·150 |
| 1·118 | 1·121 | 1·123 | 1·126 | 1·128 | 1·131 | 1·135 | 1·138 | 1·141 | 1·143 | 1·145 |
| 1·112 | 1·115 | 1·117 | 1·120 | 1·122 | 1·125 | 1·129 | 1·132 | 1·135 | 1·137 | 1·139 |
| 1·107 | 1·110 | 1·112 | 1·115 | 1·117 | 1·120 | 1·124 | 1·127 | 1·130 | 1·132 | 1·134 |
| 1·102 | 1·105 | 1·107 | 1·110 | 1·112 | 1·115 | 1·119 | 1·122 | 1·125 | 1·127 | 1·129 |
| 1·097 | 1·100 | 1·102 | 1·105 | 1·107 | 1·110 | 1·114 | 1·117 | 1·120 | 1·122 | 1·124 |
| 1·092 | 1·095 | 1·097 | 1·100 | 1·102 | 1·105 | 1·109 | 1·112 | 1·115 | 1·117 | 1·119 |
| 1·086 | 1·089 | 1·091 | 1·094 | 1·096 | 1·099 | 1·103 | 1·106 | 1·109 | 1·111 | 1·113 |
| 1·081 | 1·084 | 1·086 | 1·089 | 1·091 | 1·094 | 1·098 | 1·101 | 1·104 | 1·106 | 1·108 |
| 1·076 | 1·079 | 1·081 | 1·084 | 1·086 | 1·089 | 1·093 | 1·096 | 1·099 | 1·101 | 1·103 |
| 1·071 | 1·074 | 1·076 | 1·079 | 1·081 | 1·084 | 1·088 | 1·091 | 1·094 | 1·096 | 1·098 |
| 1·066 | 1·069 | 1·071 | 1·074 | 1·076 | 1·079 | 1·083 | 1·086 | 1·089 | 1·091 | 1·093 |
| 1·060 | 1·063 | 1·065 | 1·068 | 1·070 | 1·073 | 1·077 | 1·080 | 1·083 | 1·085 | 1·087 |
| 1·055 | 1·058 | 1·060 | 1·063 | 1·065 | 1·068 | 1·072 | 1·075 | 1·078 | 1·080 | 1·082 |
| 1·050 | 1·053 | 1·055 | 1·058 | 1·060 | 1·063 | 1·067 | 1·070 | 1·073 | 1·075 | 1·077 |
| 1·045 | 1·048 | 1·050 | 1·053 | 1·055 | 1·058 | 1·062 | 1·065 | 1·068 | 1·070 | 1·072 |
| 1·040 | 1·043 | 1·045 | 1·048 | 1·050 | 1·053 | 1·057 | 1·060 | 1·063 | 1·065 | 1·067 |
| 1·035 | 1·038 | 1·040 | 1·043 | 1·045 | 1·048 | 1·052 | 1·055 | 1·058 | 1·060 | 1·062 |
| 1·030 | 1·033 | 1·035 | 1·038 | 1·040 | 1·043 | 1·047 | 1·050 | 1·053 | 1·055 | 1·057 |
| ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |

## Flow of Steam through Pipes.

TABLE 239.—FLOW OF STEAM THROUGH PIPES.
("Steam.")

| Initial Pressure per Square Inch. | Diameter of Pipe in Inches. Length of each Pipe, 240 Diameters. | | | | | | |
|---|---|---|---|---|---|---|---|
| | ¾ | 1 | 1½ | 2 | 2½ | 3 | 4 |
| | Weight of Steam per Minute in Pounds, with One Pound Fall of Pressure. | | | | | | |
| Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. |
| 1 | 1·16 | 2·07 | 5·7 | 10·27 | 15·45 | 25·38 | 46·85 |
| 10 | 1·44 | 2·57 | 7·1 | 12·72 | 19·15 | 31·45 | 48·05 |
| 20 | 1·70 | 3·02 | 8·3 | 14·94 | 22·49 | 36·94 | 68·20 |
| 30 | 1·91 | 3·40 | 9·4 | 16·84 | 25·35 | 41·63 | 76·84 |
| 40 | 2·10 | 3·74 | 10·3 | 18·51 | 27·87 | 45·77 | 84·49 |
| 50 | 2·27 | 4·04 | 11·2 | 20·01 | 30·13 | 49·48 | 91·34 |
| 60 | 2·43 | 4·32 | 11·9 | 21·38 | 32·19 | 52·87 | 97·60 |
| 70 | 2·57 | 4·58 | 12·6 | 22·65 | 34·10 | 56·00 | 103·37 |
| 80 | 2·71 | 4·82 | 13·3 | 23·82 | 35·87 | 58·91 | 108·74 |
| 90 | 2·83 | 5·04 | 13·9 | 24·92 | 37·52 | 61·62 | 113·74 |
| 100 | 2·95 | 5·25 | 14·5 | 25·96 | 39·07 | 64·18 | 118·47 |
| 120 | 3·16 | 5·63 | 15·5 | 27·85 | 41·93 | 68·87 | 127·12 |
| 150 | 3·45 | 6·14 | 17·0 | 30·37 | 45·72 | 75·09 | 138·61 |

| Initial Pressure per Square Inch. | Diameter of Pipe in Inches. Length of each Pipe, 240 Diameters. | | | | | | |
|---|---|---|---|---|---|---|---|
| | 5 | 6 | 8 | 10 | 12 | 15 | 18 |
| | Weight of Steam per Minute in Pounds, with One Pound Fall of Pressure. | | | | | | |
| Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. |
| 1 | 77·3 | 115·9 | 211·4 | 341·1 | 502·4 | 804 | 1177 |
| 10 | 95·8 | 143·6 | 262·0 | 422·7 | 622·5 | 996 | 1458 |
| 20 | 112·6 | 168·7 | 307·8 | 496·5 | 731·3 | 1170 | 1713 |
| 30 | 126·9 | 190·1 | 346·8 | 559·5 | 824·1 | 1318 | 1930 |
| 40 | 139·5 | 209·0 | 381·3 | 615·3 | 906·0 | 1450 | 2122 |
| 50 | 150·8 | 226·0 | 412·2 | 665·0 | 979·5 | 1567 | 2294 |
| 60 | 161·1 | 241·5 | 440·5 | 710·6 | 1046·7 | 1675 | 2451 |
| 70 | 170·7 | 255·8 | 466·5 | 752·7 | 1108·5 | 1774 | 2596 |
| 80 | 179·5 | 269·0 | 490·7 | 791·7 | 1166·1 | 1866 | 2731 |
| 90 | 187·8 | 281·4 | 513·3 | 828·1 | 1219·8 | 1951 | 2856 |
| 100 | 195·6 | 293·1 | 534·6 | 862·6 | 1270·1 | 2032 | 2975 |
| 120 | 209·9 | 314·5 | 573·7 | 925·6 | 1363·3 | 2181 | 3193 |
| 150 | 228·8 | 343·0 | 625·5 | 1009·2 | 1486·5 | 2378 | 3481 |

Mr. Babcock gives the following formula for the flow of steam through pipes :—

$$W = 300\sqrt{\frac{D(p_1 - p_2)d^5}{L\left(1 + \frac{3\cdot6}{d}\right)}} \quad . \quad . \quad (19)$$

$W$ = weight of steam in pounds.
$d$ = diameter of pipe in inches.
$D$ = density or weight per cubic foot of the steam.
$p_1$ = initial pressure.
$p_2$ = pressure at end of pipe.
$L$ = length of pipe in feet.

Table 289 gives, approximately, the weight of steam which would flow through a straight smooth pipe, of which the length is equal to 240 diameters, with one pound fall of pressure.

For any other given fall of pressure, multiply the tabular weight by the square root of the given fall of pressure.

For any other given length of pipe, divide 240 by the given length in diameters, and multiply the tabular values by the square root of the quotient, to give the flow for one pound fall of pressure.

Conversely, divide the given length by 240, to find the fall of pressure for the flow given in the Table.

The loss of head due to generation of the velocity of flow, and the friction of the steam entering the pipe, is about equal to the resistance of a length of pipe equal to the quotient of 114 diameters, divided by $\left(1 + \frac{3\cdot6}{d}\right)$, in which $d$ is the diameter in inches. For the sizes given in the Table, the corresponding lengths are as follows :—

| Diameter in Inches. | Length in Diameters. | Diameter in Inches. | Length in Diameters. | Diameter in Inches. | Length in Diameters. |
|---|---|---|---|---|---|
| $\frac{3}{4}$ | 20 | 3 | 52 | 10 | 84 |
| 1 | 25 | 4 | 60 | 12 | 88 |
| $1\frac{1}{2}$ | 34 | 5 | 66 | 15 | 92 |
| 2 | 41 | 6 | 71 | 18 | 95 |
| $2\frac{1}{2}$ | 47 | 8 | 79 | | |

The resistance of a globe-valve is equal to that at the entrance of the pipe; and that at an elbow is equal to two-thirds of that of a globe-valve. The equivalent lengths respectively are to be added to the actual length of the pipe. For instance, a 4-inch pipe 120 diameters, or 40 feet, long, with a globe-valve and three elbows, would be equivalent to (120 + 60 (entrance) + 60 (globe-valve) + (40 × 3) = ) 360 diameters in

length. By the rule above given, $(360 \div 240 =)$ $1\frac{1}{2}$ lbs. is the fall or loss of pressure for the tabulated flow. Or, it would deliver $(1 \div \sqrt{1\frac{1}{2}} =)$ ·816, or 81·6 per cent. of the steam with the same loss (1 lb.) of pressure.

### Coverings for Steam-Boilers and Steam-Pipes.

The efficiency of different substances for the prevention of radiation of heat, varies generally in the inverse ratio of their conducting power for heat. From the results of experiments, it appears that the rates of condensations of steam in a naked pipe, a pipe coated with a cement, and a pipe coated with hair-felt, were proportionally as 100, 67, and 27. According to Dr. Emery, the relative efficiency of various substances as coatings, is as given in Table 290.

TABLE 290.—RELATIVE EFFICIENCY OF NON-CONDUCTORS. (Emery.)

| Substance. | Relative Efficiency. | Substance. | Relative Efficiency. |
|---|---|---|---|
| Wood felt . . . | 1·000 | Loam, dry and open | ·550 |
| Mineral wool, No. 2 . | ·832 | Slacked lime . . | ·480 |
| " " with tax | ·715 | Gas-house carbon . | ·470 |
| Sawdust . . . | ·680 | Asbestos . . . | ·363 |
| Mineral wool, No. 1 . | ·676 | Coal ashes . . | ·345 |
| Charcoal . . . | ·632 | Coke in lumps . . | ·277 |
| Pine wood,across fibre | ·553 | Air space undivided | ·136 |

### Green's Economiser.

Green's Economiser for heating the feedwater for steam-boilers, consists of a set of 4-inch cast-iron pipes 9 feet long, vertically placed in the flueway. In two extreme cases in ordinary working, the economy effected by the Economiser varied from $12\frac{1}{2}$ per cent. to 29 per cent. The burnt gases were cooled to the extent of 156° F. and 253° F. respectively.

### Loss of Steam by Condensation in Pipes.

The relative loss of heat from steam-pipes naked and clothed with wool or hair-felt, in several thicknesses, is given in Table 291. The steam pressure is taken at 75 lbs. per square inch; and the temperature of the air at 60° F. The horse-power mentioned in the Table is the standard for steam-boilers favourably received in America, according to which one horse-power is measured by the evaporation of 30 pounds of water per hour, at a working pressure of 70 lbs. per square inch from 100° F. temperature.

TABLE 291.—LOSS OF STEAM BY CONDENSATION IN PIPES.

("Steam.")

| Thickness of Covering. | Outside Diameter of Pipe. | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Two Inches. | | | Four Inches. | | | Six Inches. | | | Eight Inches. | | | Twelve Inches. | | |
| | Loss per Lineal Foot per Hour. | Ratio of Loss. | Length of Pipe per H. P. Lost. | Loss per Lineal Foot per Hour. | Ratio of Loss. | Length of Pipe per H. P. Lost. | Loss per Lineal Foot per Hour. | Ratio of Loss. | Length of Pipe per H. P. Lost. | Loss per Lineal Foot per Hour. | Ratio of Loss. | Length of Pipe per H. P. Lost. | Loss per Lineal Foot per Hour. | Ratio of Loss. | Length of Pipe per H. P. Lost. |
| Inches. | Units. | | Feet. | Units. | | Feet. | Units. | | Feet. | Units. | | Feet. | Units. | | Feet. |
| Naked. | 219·0 | 1·00 | 132 | 390·8 | 1·00 | 75 | 624·1 | 1·000 | 46 | 729·8 | 1·000 | 40 | 1077·4 | 1·000 | 26 |
| $\frac{1}{4}$ | 100·7 | ·46 | 288 | 180·9 | ·46 | 160 | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| $\frac{1}{2}$ | 65·7 | ·30 | 441 | 117·2 | ·30 | 247 | 187·2 | ·300 | 154 | 219·6 | ·301 | 132 | 301·7 | ·280 | 92 |
| 1 | 43·8 | ·20 | 662 | 73·9 | ·18 | 392 | 111·0 | ·178 | 261 | 128·3 | ·176 | 225 | 185·3 | ·172 | 157 |
| 2 | 28·4 | 13 | 1020 | 44·7 | ·11 | 648 | 66·2 | ·106 | 438 | 75·2 | ·103 | 385 | 98·0 | ·091 | 294 |
| 4 | 19·8 | ·09 | 1464 | 28·1 | ·07 | 1031 | 41·2 | ·066 | 703 | 46·0 | ·063 | 630 | 60·3 | ·056 | 486 |
| 6 | ... | ... | ... | 23·4 | ·06 | 1238 | 33·7 | ·054 | 860 | 34·3 | ·047 | 845 | 45·2 | ·042 | 642 |

## Tuck's Steam Packing.

| Diameter. | Weight per foot. | Diameter. | Weight per foot. |
|---|---|---|---|
| inches. | lbs. | inches. | lbs. |
| $\frac{3}{16}$ | ·013 | $\frac{13}{16}$ | ·255 |
| $\frac{1}{4}$ | ·024 | $\frac{7}{8}$ | ·311 |
| $\frac{5}{16}$ | ·041 | 1 | ·400 |
| $\frac{3}{8}$ | ·050 | $1\frac{1}{8}$ | ·519 |
| $\frac{7}{16}$ | ·074 | $1\frac{1}{4}$ | ·608 |
| $\frac{1}{2}$ | ·106 | $1\frac{3}{8}$ | ·728 |
| $\frac{9}{16}$ | ·131 | $1\frac{1}{2}$ | ·859 |
| $\frac{5}{8}$ | ·158 | $1\frac{5}{8}$ | ·958 |
| $\frac{11}{16}$ | ·220 | $1\frac{3}{4}$ | 1·08 |
| $\frac{3}{4}$ | ·234 | 2 | 1·48 |

## RAILWAYS.

THE lengths of lines in the United Kingdom open for traffic ı the 31st December, 1889, were in—

| | Miles Open. |
|---|---|
| England and Wales . . . . . . . | 14,034 |
| Scotland . . . . . . . . . . . | 3,118 |
| Ireland . . . . . . . . . . | 2,791 |
| | 19,943 |

', as a round number, say, 20,000 miles.

The total paid-up capital, including loans and debenture ock, was £876,595,166, or £43,960 per mile open.

The number of passengers conveyed in the year 1889, ere :—

| | | | |
|---|---|---|---|
| 1st class . . . | 30,074,810 or | 3·88 | per cent. |
| 2nd „ . . . . | 62,687,927 „ | 8·07 | „ |
| 3rd „ . . . | 682,420,336 „ | 88·05 | „ |
| Total . . . . | 775,183,073 | 100·00 | |

In goods traffic there were conveyed—

| | | | |
|---|---|---|---|
| 211,810,551 | tons of minerals, or . | 71·20 | per cent. |
| 85,695,947 | „ „ general merchandise . | 28·80 | „ |
| [illegible]498 | | 100·00 | |

The number of miles travelled by trains were as follows :—

| | Miles. |
|---|---|
| Passenger trains . . . . . . | 161,082,875 |
| Goods and mineral trains . . . . . | 138,941,233 |
| Total . . . . . . . . | 303,116,953 |

The total includes 3,092,845 miles travelled by mixed trains.

The receipts were as follows :—

| | | | |
|---|---|---|---|
| Gross receipts from passenger traffic | £32,630,724 | or 42·4 | per cent. |
| Do. Goods „ . | 41,086,333 | „ 53·3 | „ |
| Miscellaneous receipts . | 3,307,960 | „ 4·3 | „ |
| | £77,025,017 | 100·0 | |

or about £3,851 per mile open, or 5*s.* 1*d.* per train-mile run.

The total working expenditure was £40,094,116, or 52 per cent. of the receipts.

The rolling stock, on December 31, 1889, was as follows :—

| | |
|---|---|
| Locomotives (fully three-fourths of a locomotive per mile open) . . . . | 15,924 |
| Passenger carriages . . . . . . . | 36,137 |
| Other passenger train stock . . . . | 13,501 |
| Waggons . . . . . . . . . . | 503,260 |
| Sundry carriages and waggons . . . . | 14,335 |
| Passenger and goods trains carrying stock (or about 35½ vehicles per locomotive; or about 28⅓ vehicles per mile open) | 567,233 |

The average number of train-miles run per locomotive was 19,000.

The standard forms of rails are the bull-headed, the double-headed, and the flange or flat-foot rails. Of the rails used on British and Irish railways, the following are the principal dimensions :—

TABLE 292.—RAILWAY RAILS AND SLEEPERS.

| | Bull-headed Rails. | Double-headed Rails. | Flange Rails. |
|---|---|---|---|
| Weight of rail per yard | 80 lb. to 86 lb. | 82 lbs. | 74 lbs., 79 lbs. |
| Height | $5\frac{3}{16}$ ins. to $5\frac{5}{8}$ ins. | $5\frac{1}{4}$ ins., $5\frac{3}{8}$ ins. | $4\frac{9}{16}$ ins. to $4\frac{15}{16}$ ins. |
| Width of head | $2\frac{1}{2}$ ins. to $2\frac{3}{4}$ ins. | $2\frac{1}{2}$ ins. | $2\frac{1}{2}$ ins., $2\frac{3}{8}$ ins. |
| Width of flange | ... | ... | 5 ins. |
| Thickness of web | $\frac{11}{16}$ in. to $\frac{13}{16}$ in. | $\frac{11}{16}$ in. to $\frac{7}{8}$ in. | $\frac{9}{16}$ in. to 1 in. |
| Length of bars | 24 ft. to 32 ft. | 24 ft. to 30 ft. | 24 ft. to $26\frac{1}{2}$ ft. |
| Section of sleepers | 10×5 ft. to 12×6 ft. | 10×5 ft. | 10×5 ft. |
| Distance of sleepers apart | 2 ft. 6 ins. to 3 ft. 1 in. | 2 ft. 8 in. to 2 ft. 10 in. | 3 ft. |
| Weight of chair | 39 lbs. to 55 lbs. | 31 lbs. to 40 lbs. | ... |

### Locomotives and Speed of Trains.

Large express locomotives weigh in working order from 40 tons to 50 tons. The latest Midland Railway express engine weighs, in working order, 43 tons, of which the driving weight, on a single pair of wheels, is $17\frac{1}{2}$ tons. The area of fire-grate is 19·6 square feet; the heating surface is $1,240\frac{1}{2}$ square feet. The tender weighs, empty, 12 tons; and 30 tons when loaded with $3\frac{1}{2}$ tons of coal, and 3,250 gallons of water. The working steam pressure in the boiler is 160 lbs. per square inch. The cylinders are $18\frac{1}{2}$ inches in diameter, with a stroke of 26 inches. The driving wheels, single, are $7\frac{1}{2}$ feet in diameter, with a bogie in front. The total wheel-base of the engine and tender together is about 43 feet on the rails. On the London and Nottingham traffic, the average gross load weighs from 170 to 215 tons, or from 9 to 12 carriages. The time-bill speed is $53\frac{1}{2}$ miles per hour; the longest continuous run is 124 miles, and from 20 lbs. to 23 lbs. of Derbyshire coal is consumed per mile-run.

Parliamentary trains, calling at all the stations, run at an average speed of from 19 to 28 miles per hour. Express goods trains make a speed of from 20 to 25 miles per hour. The speed of coal trains is limited, as far as is practicable, to 15 miles per hour.

Coal trains generally consist of from 30 to 35 waggons, weighing from 5 tons to $5\frac{1}{2}$ tons each, and carrying 8 tons of coal. At this rate, the total load of coal for 35 waggons weighs 280 tons; add the weight of the break van at the end of the train, 10 tons, 17 cwt., and the maximum gross weight of the train is 483 tons, 7 cwt.

A 6-coupled locomotive, suited for taking this train on the

Great Northern Railway, has $5\frac{1}{2}$ feet wheels, $17\frac{1}{2}$ inch cylinders with a 26 inch stroke, with 140 lbs. pressure in the boiler; weighing, in working order, 37 tons, and with the tender full of water and coal, 68 tons. The engine, tender, and train together weigh 551 tons. Such trains are taken at a speed of 18 miles per hour; ascending inclines of 1 in 178 at a speed of 10 miles per hour; consuming 45 lbs. of coal per mile. With more powerful engines, having 19 inch cylinders, trains of 45 loaded coal waggons are taken.

Six-coupled goods engines, working at full power, exert a tractive force of from 5 tons to 6 tons at the rails. With a tractive force of 10 lbs. or 12 lbs., 1 ton of gross weight can be drawn on a level straight line at a speed of 10 miles per hour. At 60 miles per hour, the tractive force, with sharp curves and high winds, may amount to 45 lbs. for 1 ton.

## Railway Gauges.

The standard gauge of railways in Great Britain is 4 feet $8\frac{1}{2}$ inches. The same gauge is adopted in some other countries. See Table 293.

TABLE 293.—GAUGES OF THE PRINCIPAL RAILWAY SYSTEMS IN THE WORLD.

| | Ft. | Ins. | | Ft. | Ins. |
|---|---|---|---|---|---|
| Great Britain, standard gauge . . . . | 4 | $8\frac{1}{2}$ | Mexico . . . . | 4 | $8\frac{1}{2}$ |
| Ireland, stand. gauge . | 5 | 3 | | 3 | 0 |
| Central Europe, prevailing gauge . . | 4 | $8\frac{1}{2}$ | United States of America, prevailing gauges . | 4 | $8\frac{1}{2}$ |
| Russia, standard gauge | 5 | 0 | | 4 | 9 |
| Norway . . . | 4 | $8\frac{1}{2}$ | . . . . | 6 | 0 |
| | 3 | 6 | . . . . | 5 | 0 |
| Spain and Portugal, standard gauge . . | 5 | 6 | . . . . | 3 | 0 |
| Antwerp and Ghent . | 2 | 3 | . . . . | 2 | 0 |
| India, prevailing gauge | 5 | 6 | Chili . . . . | 5 | 6 |
| „ metre gauge . | 3 | $3\frac{3}{8}$ | | 4 | $8\frac{1}{2}$ |
| „ Arconum and Conjeveram . . | 3 | 6 | | 4 | 2 |
| Japan . . . . . | 3 | 6 | | 3 | 6 |
| Egypt . . . . . | 4 | $8\frac{1}{2}$ | Brazil . . . . | 5 | 6 |
| Canada . . . . | 5 | 6 | | 5 | 3 |
| | 4 | $8\frac{1}{2}$ | South Australia . . | 5 | 3 |
| | 3 | 6 | | 3 | 6 |
| | | | New South Wales . | 4 | $8\frac{1}{2}$ |
| | | | Victoria . . . . | 5 | 3 |
| | | | New Zealand . . | 5 | 3 |
| | | | | 3 | 6 |

In the United Kingdom there are a few local railways of less than the national gauge :—

| | Feet | Inches. |
|---|---|---|
| Festiniog . . . . . . . . . | 1 | 11½ |
| Talyllyn . . . . . . . . . . | 2 | 6 |
| Dinas and Snowdon, Ballymena and Larne, and others . . . . . | 3 | 0 |

### The Way: Rails, Chairs, and Sleepers.

The bull-headed rail is laid on most of the railways in Great Britain. The double-headed rail, reversible, is also in use. In Ireland, both are in use. They weigh from 82 lbs. to 86 lbs. per lineal yard. The heads are from 2½ to 2¾ inches wide; and the height of rail is from 5¼ to 5⅝ inches. The rails are of steel, rolled in bars mostly 30 feet in length. They are carried in cast-iron chairs weighing from 31 lbs. to 55 lbs. each, spiked to transverse sleepers of Baltic red wood generally 10 inches wide, 5 inches deep, and 9 feet long.

*Cost of 1 Mile of Single Line of Way on a first class Railway.*

| | £ | s. | d. |
|---|---|---|---|
| Steel rails, bull-headed, 30 feet long, 85 lbs. per yard; 133½ tons at £5 . . . . . . | 667 | 10 | 0 |
| Chairs, 3,872, at 50 lbs.; 86½ tons at £3 . . | 259 | 10 | 0 |
| Fish-plates, steel clip, 352 pairs at 40 lbs. = 6¼ tons, at £8 . . . . . . . . . | 50 | 0 | 0 |
| Bolts and nuts, 1,408 at 1½ lbs.; 1 ton at £9 10s. . . . . . . . . . . . | 9 | 10 | 0 |
| Spikes, 7,744 at 1¼ lbs.; 4¼ tons at £7 10s. . | 31 | 17 | 6 |
| Trenails, solid oak, 7,744 at £2 10s. per 1,000 . | 19 | 7 | 2 |
| Keys, oak, 3,872 at £4 per 1,000 . . . . . | 15 | 9 | 9 |
| Sleepers, creosoted, 1,936 at 4s. . . . . . . | 387 | 4 | 0 |
| Labour, 1,760 yards at 1s. 6d. . . . . . . | 132 | 0 | 0 |
| Total cost of laying . . . . . | £1,572 | 8 | 5 |
| Taking credit for old materials in case of relaying, the net cost of relaying is, say . . . | £858 | 0 | 2 |

### Centre of Gravity of Locomotives.

*To find the position of the centre of gravity of a locomotive in the horizontal sense, when the loads on the rails at the axle, and their distances apart are given.*

1. *Four-wheeled locomotive.* Multiply the load at the driving axle in tons by the length of the wheel-base in feet;

and divide by the total weight in tons. The quotient is the horizontal distance, in feet, of the centre of gravity from the other axle.

When the loads at the axles are equal, the centre of gravity lies half-way between them.

2. *Six-wheeled locomotive.* Multiply the loads at the leading and trailing axles, in tons, by their respective distances from the middle axle in feet; divide the difference of the products so found by the total weight in tons. The quotient is the horizontal distance, in feet, of the centre of gravity from the middle axle, measured towards the axle for which the greater product was found.

When the products are equal, the centre of gravity lies exactly over the middle axle.

3. *Locomotives having more than six wheels.* Select a middle axle. Multiply the loads at the axles in front of the selected axle by their distances respectively from this axle; do likewise with the axles behind the selected axle. Find the difference of the sums of the products in front and behind the selected axle; and divide it by the total weight in tons. The quotient is the distance horizontally, in feet, of the centre of gravity from the selected axle, measured in the direction for which the greater sum of the products was found.

### Tractive Power and Resistance on Railways.

For two cylinders of equal diameters, the equivalent tractive force, as at the rails for a given effective mean pressure in the cylinders, may be calculated by means of the formula—

$$T = \frac{d^2 L p}{D} \qquad \text{. . . . . (1)}$$

The equivalent effective mean pressure in the cylinders required for a given tractive force as at the rails is by formula—

$$p = \frac{DT}{d^2 L} \qquad \text{. . . . . (2)}$$

$d$ = diameter of cylinder, in inches.
$L$ = length of stroke, in inches.
$D$ = diameter of driving wheels, in inches.
$p$ = effective mean pressure, in pounds per square inch.
$T$ = equivalent tractive force, as at the rails, in pounds.

If it be assumed that the work done in the second cylinder of a compound locomotive is equal to that done in the fir-

cylinder, the formula (1) becomes available for calculating the tractive force at the rails in terms of the sizes and pressure of the first cylinder.

The proportion of the adhesion weight, or driving weight, varies from one-fifth in dry weather to one-ninth in damp weather. A fraction of from one-sixth to one-seventh may be adopted in calculation, as it can be maintained by the use of sand on the rails or other expedients. The fraction 1-6·4th gives an adhesion of 350 pounds per ton; and adopting this unit, the adhesions for various driving weights are as follows :—

| Driving Weight in tons. | Adhesion or available tractive force as at the rails. | |
|---|---|---|
| 10 | 3,500 pounds, or | 1·56 tons. |
| 20 | 7,000 ,, ,, | 3·12 ,, |
| 30 | 10,500 ,, ,, | 4·68 ,, |
| 40 | 14,000 ,, ,, | 6·25 ,, |
| 50 | 17,500 ,, ,, | 7·81 ,, |
| 60 | 21,000 ,, ,, | 9·37 ,, |

The resistance of engines and trains on railways is expressed by the formula (3), quoted from *Railway Machinery*. It applies under the following conditions :—

1. The permanent way in good order.

2. The engine, tender, and train in good order; lubricated with grease.

3. A straight and level line of rails.

4. Fair weather, and dry and clean rails.

5. An average side-wind, of average force, varying during the experiment between *slight* and *very strong*.

### Resistance of Engine, Tender, and Train.

$$R = 8 + \frac{V^2}{171} \quad . \quad . \quad . \quad . \quad (3)$$

V = speed in miles per hour.

R = total resistance in pounds per ton.

In cases of frequent sharp curves, in connection with strong side and head winds, the resistance may be augmented by one-half the given resistance on a level.

The annexed Table 294, gives the resistance per ton of engine, tender, and train, for various speeds and gradients.

TABLE 294.—RESISTANCE OF PASSENGER TRAINS.

CONDITIONS.— A good sound road. A straight line. An average side-wind. Engine, tender, and train in good working order, with grease lubrication.

| Ascending Gradients. | Speed, in Miles per Hour. | | | | | | |
|---|---|---|---|---|---|---|---|
| | 10 | 20 | 30 | 40 | 50 | 60 | 70 |
| | Total Resistance as at the Rails, in Pounds per Ton. | | | | | | |
| | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. |
| Level | 8·6 | 10·3 | 13·2 | 17·3 | 22·6 | 29 | 36·6 |
| 1 in 40 | 64 | 66 | 69 | 73 | 79 | 85 | 93 |
| 1 ,, 60 | 46 | 48 | 50 | 55 | 60 | 66 | 74 |
| 1 ,, 80 | 36 | 38 | 41 | 45 | 51 | 57 | 65 |
| 1 ,, 100 | 31 | 33 | 36 | 40 | 45 | 51 | 59 |
| 1 ,, 150 | 24 | 26 | 28 | 32 | 38 | 44 | 51 |
| 1 ,, 200 | 20 | 22 | 25 | 29 | 34 | 40 | 48 |
| 1 ,, 250 | 18 | 20 | 22 | 26 | 32 | 38 | 46 |
| 1 ,, 300 | 16 | 18 | 21 | 25 | 30 | 36 | 44 |
| 1 ,, 500 | 13 | 15 | 18 | 22 | 27 | 33 | 41 |
| 1 ,, 800 | 11 | 13 | 16 | 20 | 25 | 32 | 39 |
| 1 ,, 1000 | 11 | 12 | 15 | 19 | 25 | 30 | 39 |
| Level | 8·6 | 10·3 | 13·2 | 17·3 | 22·6 | 29 | 36·6 |

*Note.*—Fifty per cent. of the resistance as on a straight level way may be added for cases of frequent curves, of or under one mile in radius, in connection with strong side and head winds.

The general dimensions, weights, and capacity of the standard carriage stock and waggon stock of the Midland Railway, are given in Tables 298 and 299, page 553.

Supposing an engine and tender, weighing together 40 tons, and exerting a given tractive force, takes 40 loaded carriages. weighing 360 tons, at 20 miles per hour on a level, the loads which it could take if it exerted the same tractive force at higher speeds, would be proportionately as follows :—

| | | | | | | |
|---|---|---|---|---|---|---|
| At 20 | miles per hour, | 40 | carriages | weighing | 360 | tons. |
| ,, 30 | ,, ,, | 30 | ,, | ,, | 200 | ,, |
| ,, 40 | ,, ,, | 21 | ,, | ,, | 144 | ,, |
| ,, 50 | ,, ,, | 15 | ,, | ,, | 106 | ,, |
| ,, 60 | ,, ,, | 11 | ,, | ,, | 75 | ,, |

The influence of rising inclines is exemplified as follows :—

If an engine and tender, weighing together 40 tons, can draw a maximum train of 42 loaded carriages, weighing 420 tons, at 20 miles per hour on a level, it would draw only the following loads at the same speed up the annexed inclines :—

| | | | |
|---|---|---|---|
| Level . . . | 42 carriages, | weighing | 420 tons. |
| Incline, 1 in 600 . | 34 ,, | ,, | 340 ,, |
| ,, ,, 300 . | 27 ,, | ,, | 270 ,, |
| ,, ,, 150 . | 20 ,, | ,, | 200 ,, |
| ,, ,, 100 . | 15 ,, | ,, | 150 ,, |
| ,, ,, 75 . | 12 ,, | ,, | 120 ,, |
| ,, ,, 50 . | 9 ,, | ,, | 90 ,, |
| ,, ,, 40 . | 6 ,, | ,, | 65 ,, |
| ,, ,, 30 . | 5 ,, | ,, | 45 ,, |
| ,, ,, 20 . | 3 ,, | ,, | 24 ,, |
| ,, ,, 10 . | nil ,, | ,, | nil. |

## Speed of Railway Trains.

The speed of railway trains may be calculated in terms of the number of revolutions of the driving wheels of the locomotive in a given number of seconds. Let,—

$r$ = number of revolutions in the given time.
$t$ = time in seconds.
$d$ = diameter of driving wheels, in feet.
$v$ = velocity or speed in miles per hour.

The number of turns per hour is $\left(r \times \frac{60}{t} \times 60 \text{ minutes}, =\right)$

$$\frac{3{,}600\, r}{t} \quad . \quad . \quad . \quad . \quad . \qquad (a)$$

The number of turns per mile is $\left(\frac{5{,}280 \text{ feet}}{3{\cdot}1416\, d} =\right)$

$$\frac{1680{\cdot}7}{d} \quad . \quad . \quad . \quad . \quad . \qquad (b)$$

The speed in miles per hour is equal to $(a)$ divided by $(b)$ ; or, by reduction,—

$$v = \frac{2{\cdot}142\, d\, r}{t} \quad . \quad . \quad . \qquad (4)$$

The Table 295 gives multipliers in the 3rd column, by the use of which the speed of a train may be calculated in terms of the diameter of the driving wheel, column 1, for any given number of revolutions of the wheels in a given number of seconds. The speeds in the 3rd column are those due to one revolution in one second ; and the speed due to the given diameter of wheel is to be multiplied by the observed number

of turns, and the product divided by the time of observation in seconds. Or, thus,—

$$\text{Speed for 1 turn in 1 second} \times \frac{\text{number of turns observed}}{\text{time of observation in seconds}}.$$

For example, a 5 feet driving wheel makes 20 revolutions in 10 seconds. The multiplier in col. 3 for a 5 feet wheel is 10·71; and the speed is $\left(10{\cdot}71 \times \frac{20}{10} = \right)$ 21·42 miles per hour.

TABLE 295.—MULTIPLIERS FOR SPEED OF RAILWAY TRAINS.

| Diameter of Driving Wheels. 1. | | Number of Revolutions in One Mile. 2. | Speed for One Revolution in One Second. 3. | Diameter of Driving Wheels. 1. | | Number of Revolutions in One Mile. 2. | Speed for One Revolution in One Second. 3. |
|---|---|---|---|---|---|---|---|
| Ft. | Ins. | Revolutions. | Miles per Hour. | Ft. | Ins. | Revolutions. | Miles per Hour. |
| 3 | 0 | 560·2 | 6·42 | 6 | 9 | 249·0 | 14·46 |
| 3 | 3 | 517·1 | 6·96 | 7 | 0 | 240·1 | 14·99 |
| 3 | 6 | 480·2 | 7·50 | 7 | 3 | 231·8 | 15·53 |
| 3 | 9 | 448·2 | 8·03 | 7 | 6 | 224·1 | 16·06 |
| 4 | 0 | 420·2 | 8·57 | 7 | 9 | 216·9 | 16·60 |
| 4 | 3 | 395·4 | 9·10 | 8 | 0 | 210·1 | 17·14 |
| 4 | 6 | 373·5 | 9·64 | 8 | 3 | 203·7 | 17·67 |
| 4 | 9 | 353·8 | 10·17 | 8 | 6 | 197·7 | 18·21 |
| 5 | 0 | 336·1 | 10·71 | 8 | 9 | 192·7 | 18·74 |
| 5 | 3 | 320·1 | 11·25 | 9 | 0 | 186·7 | 19·28 |
| 5 | 6 | 305·6 | 11·78 | 9 | 3 | 181·7 | 19·81 |
| 5 | 9 | 292·3 | 12·32 | 9 | 6 | 176·9 | 20·35 |
| 6 | 0 | 280·1 | 12·85 | 9 | 9 | 172·4 | 20·88 |
| 6 | 3 | 268·9 | 13·39 | 10 | 0 | 168·1 | 21·42 |
| 6 | 6 | 258·6 | 13·92 | | | | |

The relations of the speed in miles per hour and the corresponding time running one mile, are expressed by the formulas (5) and (6). There are $(60 \times 60 =)$ 3,600 seconds in an hour, and the time of running one mile is equal to the quotient of 3,600 divided by the speed in miles per hour. Also the speed is equal to the quotient of 3,600 divided by the time of running one mile. Or,

$$t = \frac{3{,}600}{v} \quad . \quad . \quad . \quad . \quad (5)$$

$$v = \frac{3{,}600}{t} \quad . \quad . \quad . \quad . \quad . \quad (6)$$

$t$ = time running one mile, in seconds.
$v$ = speed in miles per hour.

By means of formula (5), the Table 296 has been calculated.

TABLE 296.—SPEED IN MILES PER HOUR, AND CORRESPONDING TIME RUNNING ONE MILE.

| Speed in Miles per Hour. | Time Running One Mile. | | | Speed in Miles per Hour. | Time Running One Mile. | | |
|---|---|---|---|---|---|---|---|
| Miles. | Seconds. | Mins. | Secs. | Miles. | Seconds. | Mins. | Secs. |
| 1 | 3600 | 60 | 0 | 29 | 124 | 2 | 4 |
| 1½ | 2400 | 40 | 0 | 30 | 120 | 2 | 0 |
| 2 | 1800 | 30 | 0 | 31 | 116 | 1 | 56 |
| 2½ | 1440 | 24 | 0 | 32 | 112 | 1 | 52 |
| 3 | 1200 | 20 | 0 | 33 | 109 | 1 | 49 |
| 3½ | 1028 | 17 | 8 | 34 | 106 | 1 | 46 |
| 4 | 900 | 15 | 0 | 35 | 103 | 1 | 43 |
| 4½ | 800 | 13 | 20 | 36 | 100 | 1 | 40 |
| 5 | 720 | 12 | 0 | 37 | 97 | 1 | 37 |
| 6 | 600 | 10 | 0 | 38 | 95 | 1 | 35 |
| 7 | 514 | 8 | 34 | 39 | 92 | 1 | 32 |
| 8 | 450 | 7 | 30 | 40 | 90 | 1 | 30 |
| 9 | 400 | 6 | 40 | 41 | 88 | 1 | 28 |
| 10 | 360 | 6 | 0 | 42 | 86 | 1 | 26 |
| 11 | 327 | 5 | 27 | 43 | 84 | 1 | 24 |
| 12 | 300 | 5 | 0 | 44 | 82 | 1 | 22 |
| 13 | 277 | 4 | 37 | 45 | 80 | 1 | 20 |
| 14 | 257 | 4 | 17 | 46 | 79 | 1 | 19 |
| 15 | 240 | 4 | 0 | 47 | 77 | 1 | 17 |
| 16 | 225 | 3 | 45 | 48 | 75 | 1 | 15 |
| 17 | 212 | 3 | 32 | 49 | 73 | 1 | 13 |
| 18 | 200 | 3 | 20 | 50 | 72 | 1 | 12 |
| 19 | 190 | 3 | 10 | 51 | 71 | 1 | 11 |
| 20 | 180 | 3 | 0 | 52 | 70 | 1 | 10 |
| 21 | 171 | 2 | 51 | 53 | 68 | 1 | 8 |
| 22 | 164 | 2 | 44 | 54 | 67 | 1 | 7 |
| 23 | 157 | 2 | 37 | 55 | 65 | 1 | 5 |
| 24 | 150 | 2 | 30 | 56 | 64 | 1 | 4 |
| 25 | 144 | 2 | 24 | 57 | 63 | 1 | 3 |
| 26 | 138 | 2 | 18 | 58 | 62 | 1 | 2 |
| 27 | 133 | 2 | 13 | 59 | 61 | 1 | 1 |
| 28 | 129 | 2 | 9 | 60 | 60 | 1 | 0 |

(*Continued on next page.*)

TABLE 296.—SPEED IN MILES PER HOUR (*continued*).

| Speed in Miles per Hour. | Time Running One Mile. | Speed in Miles per Hour. | Time Running One Mile. | Speed in Miles per Hour. | Time Running One Mile. |
|---|---|---|---|---|---|
| Miles. | Seconds. | Miles. | Seconds. | Miles. | Seconds. |
| 61 | 59 | 75 | 48 | 88 | 41 |
| 62 | 58 | 76 | 47·4 | 89 | 40·4 |
| 63 | 57 | 77 | 47 | 90 | 40 |
| 64 | 56 | 78 | 46 | 91 | 39·6 |
| 65 | 55 | 79 | 45·6 | 92 | 39·1 |
| 66 | 54·5 | 80 | 45 | 93 | 38·7 |
| 67 | 54 | 81 | 44·4 | 94 | 38·3 |
| 68 | 53 | 82 | 44 | 95 | 37·9 |
| 69 | 52 | 83 | 43·4 | 96 | 37·5 |
| 70 | 51·4 | 84 | 43 | 97 | 37·1 |
| 71 | 51 | 85 | 42 | 98 | 36·7 |
| 72 | 50 | 86 | 41·9 | 99 | 36·4 |
| 73 | 49 | 87 | 41·4 | 100 | 36 |
| 74 | 48·6 | | | | |

TABLE 297.—BULK AND WEIGHT OF GOODS, AS CONVEYED BY RAILWAY.

(Col. Kennedy.)

| Number of Kind of Goods. | Description of Goods carried. | Cubic Feet per Ton. | Weight per Cubic Foot. |
|---|---|---|---|
| No. | | Cubic Feet. | Pounds. |
| | CLASS 1. | | |
| 1 | Unpressed Cotton . . . . | 224 | 10 |
| 2 | Furniture . . . . . . . | 200 | 11 |
| 3 | Half-pressed cotton . . | 186 | 12 |
| 4 | Cotton seeds . . . . . | 186 | 12 |
| 5 | Wool . . . . . . . | 140 | 16 |
| 6 | Fruit and vegetables . . . | 100 | 22 |
| 7 | Eggs . . . . . . . . | 90 | 25 |
| | CLASS 2. | | |
| 8 | Grass . . . . . . . . . | 80 | 28 |
| 9 | Sundries . . . . . . | 80 | 28 |
| 10 | Bagging . . . . . . . | 70 | 32 |
| 11 | Commissariat stores . . | 70 | 32 |

TABLE 297.—BULK AND WEIGHT OF GOODS (*continued*).

| Number of Kind of Goods. | Description of Goods carried. | Cubic Feet per Ton. | Weight per Cubic Foot. |
|---|---|---|---|
| No. | | Cubic Feet. | Pounds. |
| | CLASS 2 (*continued*). | | |
| 12 | Full-pressed cotton | 70 | 32 |
| 13 | Flax and hemp | 70 | 32 |
| 14 | Groceries | 60 | 37 |
| 15 | Grains and seed | 60 | 37 |
| 16 | Twist | 60 | 37 |
| 17 | Sugar | 56 | 40 |
| 18 | Soap | 56 | 40 |
| 19 | Firewood | 56 | 40 |
| 20 | Salt | 51 | 44 |
| 21 | Lime | 51 | 44 |
| 22 | Dry fruits | 50 | 45 |
| | CLASS 3. | | |
| 23 | Molasses | 45 | 50 |
| 24 | Seed cotton | 45 | 50 |
| 25 | Mowra (flowers which produce spirit) | 45 | 50 |
| 26 | Timber | 45 | 50 |
| 27 | Ghee (clarified butter) | 40 | 56 |
| 28 | Oil | 40 | 56 |
| 29 | Piece goods | 40 | 56 |
| 30 | Rape | 40 | 56 |
| 31 | Beer and spirits | 36 | 62 |
| 32 | Coal | 28 | 80 |
| 33 | Paper | 28 | 80 |
| 34 | Tobacco | 28 | 80 |
| 35 | Opium | 26 | 86 |
| 36 | Machinery | 25 | 90 |
| | CLASS 4. | | |
| 37 | Cutlery | 20 | 112 |
| 38 | Potash | 20 | 112 |
| 39 | Sand | 20 | 112 |
| 40 | Colours | 18 | 124 |
| 41 | Bricks | 17 | 132 |
| 42 | Stone | 15 | 148 |
| 43 | Metal | 5 | 448 |

TABLE 298.—CARRIAGE STOCK, MIDLAND RAILWAY.

| Carriage. | Length of Body. | Compartments. | No. of Passengers. | Weight of Vehicle. | Price. |
|---|---|---|---|---|---|
| | Ft. | | | Tons. Cwts. | £ |
| 6-wheel bogie composite | 54 | 3 first class, 4 third class, 1 luggage = 8 | 58 | 23 0 | 1007 |
| 4-wheel bogie composite | 45 | 3 first class, 3 third class, 1 luggage = 6 | 48 | 18 10 | 768 |
| 4-wheel bogie third class | 43 | 7 third class | 70 | 17 15 | 620 |
| 4-wheel bogie composite | 40 | 2 first class, 3 third class, 1 luggage = 6 | 42 | 17 5 | 654 |
| 6-wheel first class | 30 | 4 first class | 24 | 10 13 | 516 |
| 6-wheel composite | 31 | 2 first class, 2 third class, 1 luggage = 5 | 32 | 11 10 | 450 |
| 6-wheel third class | 31 | 5 third class | 50 | 10 7 | 390 |

TABLE 299.—WAGON STOCK, MIDLAND RAILWAY.

| Wagon. | External Dimensions over Corner Pillars. | | Internal Dimensions. | | | Load to Carry. | Weight of Wagon. | Price. |
|---|---|---|---|---|---|---|---|---|
| | Length. | Width. | Length. | Width. | Height above Floor. | | | |
| | Ft. Ins. | Ft. Ins. | Ft. Ins. | Ft. Ins. | Ft. Ins. | Tons. | Tns. Cwts. | £ |
| Covered goods | 14 11 | 7 5 | 14 2 | 6 10 | 5 10½ | 8 | 5 3 | 72 |
| High-sided, for goods or coal | 14 11 | 7 5 | 14 6 | 7 0 | 2 10 | 8 | 5 2 | 65 |
| Low-sided | 14 11 | 7 5 | 14 6 | 7 0 | 1 9 | 8 | 4 14 | 61 |
| Cattle wagon | 18 6 | 8 0 | 17 9 | 7 4 | 7 0½ | 8 | 6 0 | 86 |

## Electrical Propulsion on Railways.

In consequence of the number of stages between the generation of steam in the stationary boilers and the hauling of the train, the efficiency of electric propulsion is relatively small. There is, first, the power consumed in driving the engine and dynamo; then, the dynamo cannot give in electrical power all the mechanical power applied to it; then there is the loss by line resistance and leakage; and the loss in the motor. These losses were such, in one case, that the efficiency of the entire plant was only 15·1 per cent. In another case, the efficiency averaged 25 per cent. The cost for power by electric agency is considered to be about four times that of direct steam power.

## TRAMWAYS.

### Length Open and Costs of Working.

The total length of tramway lines in the United Kingdom open for public traffic on the 30th June, 1889, was 949 miles, distributed as follows:—

| | Miles open. |
|---|---|
| England . . . . . . . . . . . | 758 |
| Scotland . . . . . . . . . . . | 81 |
| Ireland . . . . . . . . . . . | 110 |
| | 949 |

Of this length, 407½ miles were double line, and 541½ miles were single line: respectively 42 per cent. and 58 per cent.

The total capital expended at June 30, 1889, amounted to £13,664,591; or £14,400 per mile open.

The gross receipts for the year were £2,980,224; or £3,140 per mile open; or 11½*d.* per car mile run.

The working expenses were £2,266,681, or 76 per cent. of the receipts; or 8¾*d.* per mile run.

### Working Stock.

The working stock was as follows:—

| | |
|---|---|
| 27,060 horses, or . . | 28½ horses per mile open. |
| 539 locomotives . . | ·57 locomotives ,, |
| 3,645 cars, or . . . | 3·84 cars ,, |

62,041,013 miles were run by cars.

Flat foot girder rails of steel, weighing from 80 lbs. to 90 lbs. per yard, are now most commonly laid. They are about 6 inches in height, and from 5 inches to 6 inches wide at the flange-base.

Cars capable of holding 20 passengers inside, and 22 outside, weigh about 2½ tons each. The gross weight, fully loaded, is 5½ tons. The body of the car is 15¼ feet in length, 6 feet 8 inches wide, outside measurement. The total length of the car is 21¼ feet, allowing 3 feet at each end for the platform.

The average resistance to traction is about 30 lbs. per ton of car and its load. When the rails are wet and clean, straight and new, a minimum of 15 lbs. per ton may be reached. An occasional maximum resistance of 60 lbs. per ton may be reached; the augmentation being due mostly to the clogging of the grooves of the rails.

### Cost per Mile.

*(Single line, of sample of Tramway: girder rail 80 lbs. per yard, 7 inches high.)*

| | £ | s. | d. |
|---|---|---|---|
| Steel rails, 80 lbs. per yard, 125¾ tons, @ £8 14*s*. | 1,094 | 0 | 6 |
| Wrought-iron fish-plates, 4¾ tons, @ £8 . . | 38 | 0 | 0 |
| ,, ,, bolts and nuts, 9 cwt., at 11*s*. . | 4 | 19 | 0 |
| Lifting and carting away, 522 cubic yards, @ 1*s*. 9*d*. . . . . . . . . . . | 45 | 13 | 6 |
| Excavation, &c., 1,108 cubic yards, @ 2*s*. . . | 110 | 16 | 0 |
| Portland cement concrete, 6 inches thick, 782 cubic yards, @ 17*s*. . . . . . . | 664 | 14 | 0 |
| Laying tramway, 1,760 yards, @ 1*s*. 8*d*. . . | 146 | 13 | 4 |
| Total for the way . . . . . . | 2,104 | 16 | 4 |
| Paving, &c., 2,836 square yards, @ 7*s*. 3*d*. . . | 1,028 | 1 | 0 |
| Paving in cement and sand, next rails, 1,564 square yards, @ 7*s*. 7*d*. . . . . . . | 593 | 0 | 4 |
| Grouting joints of sets with bitumen, 4,400 square yards, @ 1*s*. 3½*d*. . . . . . . | 284 | 3 | 4 |
| Total for paving . . . . . . . | 1,905 | 4 | 8 |
| Total for way and paving . . . . . | 4,010 | 1 | 0 |

### Steam Power on Tramways.

Kitson & Co.'s engines on the Birmingham Central Tramways weigh, with water and coal, from 9 to 10 tons. They draw a car holding 60 passengers. On the same line, the engines of the Falcon Company have 8-inch cylinders, with 14 inches of stroke, and 2½ feet wheels. In drawing two loaded cars weighing together 18½ tons, at a speed of 6 miles per hour, on a gradient of 1 in 25, they indicated 40 horse-power, consuming from 8 to 9 pounds of coke per mile.

### Compressed-Air Tramway Engines.

Mekarski's system of employing compressed air, heated by an admixture of steam, is in operation on the Nantes tramways. The efficiency of the air-compressors is 76 per cent. in volume of air delivered: one kilogramme, or 2·205 pounds of air, compressed to a pressure of 426 lbs. per square inch, supplies energy equivalent to 90,375 foot-pounds, and 100 kilogrammes, or 220 pounds of compressed air, is sufficient to propel a car of 8 tons loaded weight for a distance of from 7½ to 8 or 9 miles. The cars have seats for 19 persons, a platform for 15 or 16 at one end, and the heater and the driver's cab at the other end. The total length is 23¼ feet, and the

width is 7¼ feet. The weight of the car is 6 tons empty, 8 tons full, of which the adhesion weight is 4½ tons. The compressed air is contained in 10 cylindrical reservoirs, placed transversely underneath the platform, connected by pipes, in two sets, to form a working and a reserve battery, having respectively 70 and 28 cubic feet of capacity; together, 98 cubic feet, and holding, when charged, 220 pounds of compressed-air. The working cylinders are outside, 5¼ inches in diameter, with a stroke of 10¼ inches; the compressed air is cut off at one-third. The driving wheels are 27½ inches in diameter. The heater has a capacity of 28 gallons, and the water is heated to 300° F. by the injection of steam before starting. The consumption of compressed air varies from 23 pounds to 28½ pounds per mile. The working cost is at the rate of about 6*d*. per mile-run.

From the results of trials made by D. K. Clark of one of Hughes & Lancaster's low-pressure compressed-air tramcars, propelled by means of four single-acting 5-inch cylinders, of 3 inches stroke, it appears that the consumption of compressed air was at the rate of 30½ pounds per mile-run for a level. The car, with passengers, weighed 4¼ tons; and the work done was at the rate of 22,070 foot-pounds per pound of air. The maximum working pressure of compressed air was 132 lbs. per square inch.

### Electrical Propulsion on Tramways.

The Bessbrook and Newry Tramway, 3 miles long, has an average gradient of 1 in 86, and a maximum gradient of 1 in 50; and is to a 3 feet gauge. It is worked by electric power. Two passenger cars, 33 feet and 21 feet 8 inches long, are each provided with a motor. The longer car weighs 8¼ tons, comprising 2 tons, 1 cwt., 1 quarter, the weight of the dynamo, bed-plate, armature, and accessories. The shorter car is similar to the longer; and there is a third passenger car 33 feet long, weighing 5½ tons. The generator is worked by a fall of water, 28 feet high. There are two generating dynamos for a normal output of 250 volts, 72 ampères, at a speed of 1,000 revolutions per minute, for which the electrical efficiency is 92·2 per cent., and the commercial efficiency 90·4 per cent. The conductor is of channel steel, laid midway between the rails or under insulators. The circuit is completed by the rails of the permanent way, which are uninsulated. Each locomotive car is fitted with an Edison-Hopkinson dynamo-motor. A speed of one mile per hour corresponds to 100 revolutions of the dynamo-axle per minute. Three trains, having six trucks, four trucks, and no trucks respectively,

and weighing 28·64 tons, 21·9 tons, and 8·8 tons, including the weight of the locomotive, were tried for efficiency. The leading results are given in Table 300, and the percentages in Table 301.

### TABLE 300.—BESSBROOK AND NEWRY TRAMWAYS: RESULTS OF ELECTRICAL TRACTION.

| Items. | First Journey. | Second Journey. | Third Journey. |
|---|---|---|---|
| | Tns. Cwts. Qrs. | Tns. Cwts. Qrs. | Tns. Cwts. Qrs. |
| Gross load . . . . . . | 28 12 3 | 21 18 0 | 8 16 0 |
| Average speed, in miles per hour | 5·7 | 7·2 | 11·3 |
| Total energy of water, in foot-pounds . . . . . . | 60,291,000 | 40,860,600 | 27,522,000 |
| Total electrical energy developed by generator, in foot-pounds . . . . . . | 35,871,000 | 21,516,000 | 9,332,400 |
| Total mechanical energy developed by motor, in foot-pounds | 24,928,200 | 15,493,500 | 7,170,900 |
| Sum of electrical losses, in foot-pounds . . . . . . | 12,493,800 | 5,841,000 | 2,174,700 |
| Loss in generator, in foot-pounds | 3,343,000 | 1,735,800 | 801,900 |
| ,, leakage ,, ,, | 1,420,300 | 1,029,600 | 775,500 |
| ,, resistance of line, in foot pounds . . . | 3,613,500 | 1,296,900 | 287,100 |
| ,, motor, in foot-pounds . | 4,098,600 | 1,791,900 | 326,700 |
| Total work done against gravity | 11,867,400 | 7,356,800 | 2,858,300 |
| ,, ,, friction | 13,060,800 | 8,136,700 | 4,312,600 |
| Average tractive forces, exclusive of gravity, in pounds per ton . . . . . . . | 28·9 | 27·4 | 37·1 |

### TABLE 301.—BESSBROOK AND NEWRY TRAMWAYS: PERCENTAGE DISTRIBUTION OF POWER.

| Items. | 1st Journey. | | 2nd Journey. | | 3rd Journey. | |
|---|---|---|---|---|---|---|
| | Water Power. | Total Power of Generator. | Water Power. | Total Power of Generator. | Water Power. | Total Power of Generator. |
| | Per cent. | Per cent. | Per cent. | Per cent. | Per cent. | Per cent. |
| Water power . . | 100·0 | ... | 100·0 | ... | 100·0 | ... |
| Generator power . | 59·5 | 100·0 | 52·6 | 100·0 | 33·9 | 100·0 |
| Net motor power . | 41·3 | 69·4 | 37·9 | 72·0 | 26·1 | 76·8 |
| Loss in generator . | 5·5 | 9·3 | 4·2 | 8·0 | 2·9 | 8·6 |
| ,, leakage . | 2·3 | 3·9 | 2·5 | 4·8 | 2·8 | 8·3 |
| ,, line resistance . | 6·0 | 10·6 | 3·2 | 6·0 | 1·0 | 3·1 |
| ,, in motor . | 6·8 | 11·4 | 4·4 | 8·3 | 1·2 | 3·[illegible] |

The Barking Road section of the North Metropolitan Tramways is worked by electrical power by contract, charged for at the rate of about 4½*d*. per car mile run, including the wages of the driver.

### Resistance to Traction on Common Roads.

(F. V. Greene.)

| Way. | Pounds per ton. |
|---|---|
| Iron | 10 lbs. |
| Asphalte | 15 „ |
| Wood | 21 „ |
| Best stone blocks | 33 „ |
| Inferior stone blocks | 50 „ |
| Average cobble stone | 90 „ |
| Macadam | 100 „ |
| Earth | 200 „ |

## STEAM-SHIPS.

The gross register tonnage of a ship is reckoned at the rate of 100 cubic feet of capacity per ton, by the formula :—

$$\text{Register tonnage} = C\,\frac{L\,B\,D}{100} \qquad (1)$$

L = inside length on the upper deck from the plank at the stem to the plank at the stern, in feet.
B = inside main breadth from ceiling to ceiling, in feet.
D = inside midship depth from the upper deck to the ceiling at the limber strake, in feet.
C = a constant, the values of which are as follows :—

| | | C |
|---|---|---|
| Sailing ships | | ·70 |
| Steam vessels and clippers | Ships of 2 decks | ·65 |
| | Ships of 3 decks | ·68 |
| Yachts | Above 60 tons | ·50 |
| | Under 60 tons | ·45 |

The values thus obtained express the entire cubical capacity of the ship. Deductions are allowed for buildings erected for the shelter of passengers only, for crew space at the rate of 72 cubic feet per man, and propelling space. This third item, for screw steamers, is taken as 32 per cent. if the cubic content is 13 per cent. and under 20 per cent. of the gross tonnage ; if the space is smaller than 13 per cent. and larger

than 20 per cent., deduct 32 per cent., or $1\frac{3}{4}$ times the content. For paddle-steamers, deduct 37 per cent., if the content is 20 per cent. and under 30 per cent.; if the space is smaller than 20 per cent. or larger than 30 per cent., deduct 37 per cent., or $1\frac{1}{2}$ times the content.

Builder's measurement is compnted in terms of the length and the breadth by the formula :—

$$\text{Tonnage} = \frac{(L - \cdot 60\ B)\ 1 \cdot 5\ B}{94} \quad . \quad . \quad (2)$$

L = length measured from the back of the main stern post to a vertical from the fore part of the main stem under the bowsprit, in feet.

B = the extreme breadth to the outside planking, exclusive of doubling planks, in feet.

## Resistance of Ships.

The thrust on the collars of the propeller shaft is a measure of the power actually exerted for the propulsion of the vessel. Let P = the thrust or pressure of the propeller against the thrust bearing in pounds; and S = the speed of the ship in feet per minute; the effective horse-power is,—

$$\frac{S \times P}{33{,}000}$$

Taking it as two-thirds of the indicator power, which is a usual proportion, $\frac{2}{3}$ I. H. P. $= \frac{S \times P}{33{,}000}$; and

$$P = \text{I. H. P} \times \frac{22{,}000}{S} \quad . \quad . \quad . \quad (3)$$

The effective indicator horse-power required to propel a steam-ship is given by the following formulæ :—

$$\text{Eff. I. H. P.} = \frac{D^{\frac{2}{3}} \times S^3}{C} \quad . \quad . \quad (4)$$

$$\text{Eff. I. H. P.} = \frac{A \times S^3}{K} \quad . \quad . \quad . \quad (5)$$

I. H. P. = effective indicator horse-power, or the net indicator power for propulsion.

D = displacement, in tons.

S = speed in knots per hour.

A = immersed mid ship section, in square feet.

C = a constant.

K = a constant.

The results obtained by means of these formulæ are to be taken as only approximate. The first is the more trustworthy. The following are a few values of the constants C and K :—

| Length. | Speed. | C. | K. |
|---|---|---|---|
| Less than 200 feet . | About 10 knots | 210 | 600 |
| 200 to 250 feet . . | 11 ,, | 220 | 600 |
| 250 to 300 ,, . | 12 ,, | 240 | 620 |
| 300 to 400 ,, . . | 15 ,, | 250 | 650 |
| Over 400 ,, . | 17 ,, | 240 | 620 |

The effective indicator horse-power may also be calculated in terms of the area of wetted surface, by the formula :—

$$\text{Eff. I. H. P.} = \frac{W \times S^3}{20,000} \quad . \quad . \quad . \quad (6)$$

W = area of wetted surface, in square feet.
S = speed in knots per hour.

## Forced Draught in Marine Boilers.

A blast of compressed air was applied in the chimney of the "Résolue," with the results given in Table 302.

TABLE 302.—COMPRESSED-AIR EXHAUSTING BLAST ON THE S.S. "RÉSOLUE."

| Horse-power of the Blowing Engine. | Horse-Power of the Main Engine. | Coal Consumed per Hour (Anzin briquettes). | Coal per Indicator Horse-Power per Hour. | Water Evaporated per Pound of Coal. |
|---|---|---|---|---|
| I. H.-P. | I. H.-P. | Pounds. | Pounds. | Pounds. |
| 0·00 natural draught | 57·5 | 213 | 3·72 | 10·77 |
| 0·96 | 88·8 | 289 | 3·26 | 8·82 |
| 2·00 | 100·5 | 315 | 3·12 | 8·00 |
| 3·00 | 106·1 | 321 | 3·04 | 7·82 |
| 4·20 | 118·8 | 348 | 2·93 | 7·82 |
| 5·00 | 119·8 | 374 | 3·12 | 7·53 |
| 6·00 | 127·9 | 400 | 3·12 | 7·00 |
| 7·40 | 135·7 | 420 | 3.10 | 7·03 |

The fuel consumed and the power were doubled, but the [illegible]orative efficiency was reduced.

From the results of trials on ships of the Navy, it appears that with open stokeholds and natural draught versus closed stokeholds and forced draught, the indicator power of the engines was increased by $52\frac{1}{2}$ per cent.; and 65 per ton of boiler.

By Mr. Fothergill's system of closed ashpits and forced draught, there is an economy of 20 per cent. of coal for steaming.

With a combined forced and induced draught by compressed air into the ashpit, the speed of a steam launch was increased from 3 knots to 6 knots per hour. The quantity of water evaporated per hour was trebled.

By an induced draught caused by an exhausting fan at the base of the chimney of a marine boiler, nearly three times as much water was evaporated as by natural draught; about 6 per cent. less water was evaporated per pound of coal.

## Average Weight of Steam-Engines with Boilers, Water, and all Fittings per Indicator Horse-power.

(F. C. Marshall.)

| | Per I. H. P. |
|---|---|
| Merchant steamer | 180 lbs. |
| Royal Navy | 360 ,, |
| Engines specially designed for light-draught vessels | 280 ,, |
| Royal Navy, Polyphemus Class | 180 ,, |
| Locomotive | 140 ,, |
| Torpedo vessels | 60 ,, |
| Ordinary Marine boilers, with water | 196 ,, |
| Locomotive boilers, with water | 60 ,, |

## Average Proportions and Results of Performance of Compound Engines.

(F. C. Marshall.)

| | | Average. |
|---|---|---|
| Speed of piston, in feet per minute | from 350 to 550 | 467 ft. |
| Working pressure of steam above the atmosphere | ,, 70 lbs. to 100 lbs. | 77·4 lbs. |
| Condensing surface | ,, 1,518 to 7,427 sq. ft. | |
| Heating surface | ,, 2,379 to 11,045 ,, | |
| ,, ,, per I. H. P. | ,, 2·77 to 6·30 ,, | 3·92 sq. ft. |
| Indicator horse-power | ,, 560 to 2,745 I. H. P. | |
| Coal consumption in 24 hours | ,, 11 to 51·9 tons. | |

| | | Average. |
|---|---|---|
| Coal consumption per I. H. P. per hour . . . | from $1\frac{1}{2}$ to 2 lbs. . . | 1·83 lbs. |
| Heating surface per pound of coal per hour . . . | „ 1·65 to 3·12 sq. ft. . | 2·18 sq. ft. |

The above proportions apply with sufficient nearness to the multiple compound practice of to-day, excepting that higher pressures are employed, up to 160 lbs. per square inch in the boiler; and that the consumption of coal may, under good conditions, be reduced as low as 1·44 lbs. per I. H. P. per hour.

### Horse-power of Marine Engines.

The North East Coast Institution of Engineers and Shipbuilders have framed a general rule for what they designate the Normal Indicator Horse-power on loaded trial trip of surface-condensing marine screw engines working at any boiler pressure between 50 lbs. and 250 lbs. per square inch.

$$\text{(For screw engines) N. I. H. P.} = \frac{(D^2 \sqrt[3]{S} + 3H)\sqrt[3]{P}}{100} \quad . \quad (7)$$

D = diameter of low-pressure cylinder, in inches.
S = stroke of piston, in inches.
P = working boiler pressure, in lbs. per square inch above the atmosphere.
H = heating surface of boilers, in square feet.
$Pm$ = mean pressure in lbs. per square inch, reduced to low-pressure cylinder.
R = revolutions per minute.
N. I. H. P. = maximum normal indicator horse-power, or loaded trial trip, of surface-condensing marine screw engines.

The conditions assumed as normal are: 1. That the steam, whatever its initial pressure, is expanded in the engines to the same pressure. 2. That the expansion is effected in the engines with the same degree of efficiency for all pressures between 50 lbs. and 250 lbs. per square inch. On this condition, for the higher pressures, engines of triple, quadruple, or more expansions, must be employed, the number of expansions depending on the initial pressure. From conditions 1 and 2, it follows that the mean pressure reduced to the low-pressure cylinder, $Pm$, may be assumed as proportional to the cube root of the boiler pressure, $\sqrt[3]{P}$; and that its actual

loaded trial-trip value may be taken without sensible error as $5\cdot6\ \sqrt[3]{P}$. 3. That the piston speeds of engines of different lengths of stroke, are proportional to the cube roots of their respective strokes; and that the actual loaded trial-trip value of piston speed may be taken as $144\ \sqrt[3]{S}$. 4. That in all cases where the engines and boilers bear to each other such proportions as to prevent condition 1 from being fulfilled, without thereby violating condition 3, the coal consumption per indicator horse-power will not be affected, but will be constant for the same boiler pressure. 5. That the boilers are constructed in accordance with the fair average practice of the present day; that if forced draught be employed, it does not exceed the average chimney draught; that the horse-power is proportional to the heating surface, H., and to the cube root of the pressure, $\sqrt[3]{P}$; and that the actual loaded trial-trip horse-power may be taken as $\frac{H\ \sqrt[3]{P}}{16}$. 6. That the efficiency of the engine mechanism is constant, and that the propeller is such that the engines may utilise the boiler power in the manner prescribed in conditions 3 and 4.

**Deductions from the Rule.**

$$\text{I. H. P. of engines} = D^2\ \sqrt[3]{P\ S} \quad . \quad . \quad . \qquad (8)$$

$$\text{I. H. P. of boilers} = \frac{H\ \sqrt[3]{P}}{16} \quad . \quad . \quad . \quad . \qquad (9)$$

These values (8) and (9) are equal; and, reducing.—

$$\text{(For screw engines) } H = \frac{D^2\ \sqrt[3]{S}}{3\cdot25} \quad . \quad . \qquad (10)$$

Assuming that half the sum of the powers calculated for the engines and boilers taken together, or the mean of the powers, represents the effective power of the system,—

N. I. H. P. of screw engines and boilers jointly =

$$\frac{(D^2\ \sqrt[3]{S} + 3\ H)\ \sqrt[3]{P}}{100} \quad . \quad . \quad . \qquad (11)$$

For paddle engines, the same formula is available, with a suitable co-efficient. Taking the piston speed at $90\ \sqrt[3]{S}$:—

$$\text{(For paddle engines) N. I. H. P.} = \frac{(D^2\ \sqrt[3]{S} + 5\ H)\ \sqrt[3]{P}}{160} \qquad (12)$$

$$H = \frac{D^2\ \sqrt[3]{S}}{5\cdot2} \quad . \quad . \quad . \quad . \qquad (13)$$

What is known as nominal horse-power may be valued at one-sixth of the normal indicator horse-power.

In America, a standard of horse-power has come into practice, measured by 30 pounds of water evaporated per hour, at a pressure of 70 lbs. per square inch above the atmosphere, from 100° F. per horse-power.

## PUMPING STEAM-ENGINES AND PUMPS.

The net work done, or duty effected by a pump, is equal to the product of the weight in pounds of water lifted by the height in feet through which it is raised. The efficiency of the pump is the ratio of the effective work done to the whole work expended in driving the pump. The efficiency increases generally with the height of the lift, as shown in Table 303.

TABLE 303.—EFFICIENCY, OR RATIO OF DUTY TO ENGINE-POWER, OF LARGE PUMPING ENGINES.

| | Head, in Feet. | Efficiency per Cent. |
|---|---|---|
| Cornish pumping engines . . | 140 | 90·8 |
| Rotative beam engine . . . | 20·5 | 86 |
| Rotative Woolf beam . . | 210 | 85 to 88 |
| Rotative receiver beam . . | 35 | 77·4 |
| Rotative compound beam . . | 169 | 83·7 |
| Worthington pump . . . | 60·6 | 85 |
| " " . . . | 148·5 | 91·5 |

The duty of a pumping engine is defined as the number of pounds of water lifted one foot high, by the consumption of 1 cwt. of coal (112 pounds). The duty may be deduced from the performance of a pumping engine expressed in pounds of coal consumed per indicator horse-power, by dividing 1,980,000 by the given pounds of coal, and multiplying the quotient by 112.

Conversely, the fuel consumed per net horse-power of the pump may be calculated from the duty expressed in foot-pounds per cwt. of coal, by dividing the duty by 112, to give the duty per pound of fuel; and dividing the quotient into

1,980,000. The final quotient is the quantity of coal in pounds consumed per horse-power per hour.

Or, divide 222 by the duty in millions of pounds lifted one foot per cwt. of fuel. The quotient is the quantity of coal consumed in pounds per horse-power per hour.

The duty or effective horse-power of pumping engines, varies from 75 per cent. to 85 per cent. of the indicator power, for vertical direct-acting and beam-rotative engines. For horizontal pumping engines, the duty horse-power is about 85 per cent. of the indicator power. The Worthington horizontal compound direct-action pumping engine, tested by Mr. J. G. Mair, realised a duty power 91½ per cent. of the indicator power; or, deducting 3½ per cent. for the aid of an auxiliary engine to work the air-pump and the feed-pump, a net efficiency of 88 per cent. is obtained.

The slip of large reciprocating pumps varies from 5 per cent. to 1½ per cent., or occasionally less: showing that from 95 per cent. to 98½ per cent. of the working capacity of the pump is utilised. An average of 2½ per cent. of slip may be taken. It is customary to include an allowance of 5 per cent. for slip. In rare instances there is no slip.

Of the four values, the area and stroke of the pump, and the area and stroke of the steam cylinder, or of the second cylinder of a compound engine, to find the value of one, when those of the three others are known. The product of the area of the steam cylinder by the effective average pressure per square inch is equal to the product of the area of the pump barrel by the load in pounds per square inch, plus an allowance, say, of 25 per cent. to overcome frictional resistance. Whence the following rules, in which the areas of the cylinder and the pump-barrel are expressed in square inches, and the pressures and loads in pounds per square inch:—

1. *To find the required area of the cylinder.* Multiply the area of the air-pump by the load on the pump, and divide by the effective average pressure of steam available in the cylinder. Add 25 per cent. of the area for friction.

2. *To find the average effective steam pressure required in the cylinder.* Multiply the area of the pump by the load on the pump, and divide by the area of the cylinder. The quotient is the effective average pressure required to balance the load. Add 25 per cent. of the pressure for friction.

3. *To find the load against which the pump will deliver water.* Multiply the area of the cylinder by the effective average steam pressure, and divide by the area of the pump. From the quotient deduct 20 per cent. for friction; the remainder is the pressure or load under which water will be delivered.

4. *To find the area of the pump-barrel.* Multiply the area of the cylinder by the effective average steam pressure, and divide by the load. Deduct 20 per cent. for friction; the remainder is the area of pump-barrel required to balance the load.

In the case of compound engines, the area of the second cylinder is to be taken into the calculation; and the effective average pressure in the first cylinder is to be reduced in the ratio of the area of the second cylinder to that of the first cylinder; and, thus reduced, added to the effective average pressure in the second cylinder. The sum is to be adopted for calculation as in the case of a single cylinder.

## Speed of Pistons.

The speed of steam-pistons may be from 100 feet to 200 feet per minute. The water may pass through the service-pipes at speeds of from 150 feet to 350 feet.

Six-inch three-throw pumps, raising water, performed the following duties for corresponding lifts, in parts of the indicator power:—

| Water per Hour. | Lift. | Efficiency. |
|---|---|---|
| 120 barrels | 165 feet | 77 per cent. |
| 160 " | 140 " | 65·6 " |
| 80 " | 54 " | 78·5 " |
| 250 " | 48 " | 45·0 " |

## Centrifugal Pumps.

TABLE 304.—RAISING WATER FROM DEEP WELLS.

(Appleby.)

| Quantity of Water lifted per Hour. | Lift for One Man on Crank. | Lift for One Donkey Engine. | Lift for One Horse Engine. | Lift for One Horse-Power Steam-Engine. |
|---|---|---|---|---|
| Gallons. | Feet. | Feet. | Feet. | Feet. |
| 200 | 90 | 180 | 630 | 990 |
| 350 | 52 | 102 | 357 | 561 |
| 500 | 36 | 72 | 252 | 396 |
| 650 | 28 | 56 | 196 | 308 |
| 800 | 22 | 45 | 154 | 242 |
| 1000 | 18 | 36 | 126 | 198 |

The maximum duty of a centrifugal pump worked by a steam-engine, according to the late Mr. David Thomson, varies from 55 per cent. for smaller pumps to 70 per cent. for larger pumps. For lifts of from 15 to 20 feet, they are as economical of power as ordinary pumps; for lifts of 4 or 5 feet they are more efficient.

The height to which water would ascend in a pipe by the action of centrifugal force, would, if there were no other resistances, be that due to the velocity of the circumference of the revolving wheel, or to $\frac{v^2}{2g}$ or $\frac{v^2}{64}$.

### Chain Pumps.

An endless chain, fitted with floats, circulating continuously, and drawing up an inclined plane, utilises in duty, 40 per cent. of the power applied. Lifting water through a vertical pipe, the efficiency is 65 per cent. The slip is about 17 per cent.

### Hydraulic Rams.

The efficiency of the hydraulic ram is expressed by Daubuisson's formula:—

$$\frac{d'h'}{dh} = 1{\cdot}42 - {\cdot}28\sqrt{\frac{h'}{h}} \quad . \quad . \quad . \quad (1)$$

$d$ = quantity of water used, in gallons per minute.
$d'$ = quantity of water raised, in gallons per minute.
$h$ = head used, in feet.
$h'$ = lift, in feet.

TABLE 305.—EFFICIENCY OF HYDRAULIC RAMS.

| Ratio of Lift to Fall. Fall = 1. | Efficiency. | Ratio of Lift to Fall. Fall = 1. | Efficiency. | Ratio of Lift to Fall. Fall = 1. | Efficiency. | Ratio of Lift to Fall. Fall = 1. | Efficiency. |
|---|---|---|---|---|---|---|---|
| Ratio. | Per cent. | Ratio. | Per cent. | Ratio. | Per cent. | Ratio. | Per cent. |
| 4 | 72 | 10 | 44 | 16 | 25 | 22 | 9 |
| 5 | 66 | 11 | 41 | 17 | 22 | 23 | 7 |
| 6 | 61 | 12 | 37 | 18 | 19 | 24 | 4 |
| 7 | 57 | 13 | 34 | 19 | 17 | 25 | 2 |
| 8 | 52 | 14 | 31 | 20 | 14 | 26 | 0 |
| 9 | 48 | 15 | 28 | 21 | 12 | | |

The Table 305 of efficiencies was calculated by means of

this formula, only five-sixths of the calculated values being taken, in order to cover contingencies.

According to Eytelwein's formula, the proper diameter of the driving-pipe, in inches, is equal to the square root of the quantity of water in gallons per minute.

### Cast-Iron Water-Pipes.

The suitable thickness of cast-iron water-pipes is given by the formulæ,—

$$t = \cdot 25 + \frac{Hd}{9600} \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

$$t = \cdot 25 + \frac{pd}{4250} \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

$t$ = thickness of pipe, in inches.
H = head of pressure, in feet of water.
$d$ = inside diameter of pipe, in inches.
$p$ = the interior pressure, in pounds per square inch.

For the usual head, 300 feet of water, the formula (2) becomes,—

$$t = \cdot 25 + \cdot 031\, d \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

For socket ends, the equivalent length of pipe, equal in weight to that of the socket, is given by the formula,—

$$\text{Equivalent length in inches} = 7 + \frac{d}{15} \quad . \quad . \quad . \quad (5)$$

$$\text{,, \quad ,, \quad feet} = \cdot 6 + \frac{d}{180} \quad . \quad . \quad . \quad (6)$$

The additional weight for a pair of joint-flanges is equivalent to that of a lineal foot of pipe.

## COAL GAS, &c.

TABLE 306.—PRODUCTS OF DISTILLATION OF COAL, PER TON.

| | Wigan Cannel. | Wigan Coal. | Newcastle Coal. |
|---|---|---|---|
| Gas . . . . . | 10,900 cub. ft. | 9980 cub. ft. | 9700 cub. ft. |
| Coke . . . . . | 1436 pounds. | 1517 pounds | 1540 pounds |
| Tar . . . . . | 17 gallons | 11 gallons | 9 gallons |
| Ammoniacal liquor . | 18 ,, | 20 ,, | 10 ,, |
| Illuminating power of gas . . . | 24 sperm candles | 15 candles | 15 candles |
| Percentage of coke . | 64 per cent. | 68 per cent. | 70 per cent. |

**Average Yield of Bituminous Coal, by Weight.**

(Newbigging.)

| | Per cent. |
|---|---|
| Gas . . . . . . . . | 18 |
| Coke and breeze . . . . . . | 68 |
| Tar . . . . . . . . | 5 |
| Ammoniacal liquor . . . . . | 9 |
| | 100 |

TABLE 307.—RESULTS OF DISTILLATION OF ONE TON OF NEWCASTLE CANNEL COAL, FOR GAS AND FOR OIL.

(Gesner.)

| Distilled for Gas, at from 1000° to 1200° F. | | Distilled for Oil, at from 750° to 800° F. | |
|---|---|---|---|
| Gas . . | 7450 cub. ft. | Gas . . | 1400 cub. ft. |
| Tar . . . | $18\frac{1}{2}$ gallons | Crude oil . . | 68 gallons |
| Coke . . | 1200 pounds | Coke . . | 1280 pounds |
| *Products of the Tar.* | | *Products of the Crude Oil.* | |
| Benzole . . | 3 pints | Eupion . . | 2 gallons |
| Coal-tar naphtha . | 3 gallons | Lamp Oil . . | $22\frac{1}{2}$ " |
| Heavy oil and naphthaline . | 9 " | Heavy oil and paraffin . | 24 " |
| | $12\frac{3}{8}$ " | | $48\frac{1}{2}$ " |

TABLE 308.—AVERAGE COMPOSITION OF LONDON GAS, BY VOLUME.

(Dr. Letheby, 1866.)

| Description of Gas. | Common Gas. | Cannel Gas. |
|---|---|---|
| | Per cent. | Per cent. |
| Hydrogen . . . . . . | 46·0 | 27·7 |
| Light carburetted hydrogen . | 39·5 | 50·0 |
| Olefiant gas . . . . . | 3·8 | 13·0 |
| Carbonic oxide . . . . . | 7·5 | 6·8 |
| Carbonic acid . . . . . | 0·7 | 0·1 |
| Aqueous vapour . . . . . | 2·0 | 2·0 |
| Nitrogen . . . . . . | 0·5 | 0·4 |
| | 100·0 | 100·0 |

TABLE 309.—LONDON COAL GAS:—COMPOSITION AND CALORIFIC VALUE.

(Society of Arts, 1889.)

| Constituents. | Proportion by Volume. | Weight of One Cubic Foot of the Gas named in Column 1. (At Standard Pressure and Temperature.) | Weight in One Cubic Foot of Coal Gas. (At Standard Pressure and Temperature.) | Proportion by Weight. | Calorific Value per Pound of the Gas down to 100° C. | Calorific Value per Pound of Coal Gas down to 100° C. | Proportional Weight of Oxygen Required for Complete Combustion of One Pound of the Gas. | Weight of Oxygen Required for Complete Combustion of One Pound of Coal Gas. | Weight of Products of Combustion for One Pound of Coal Gas. Steam. | Weight of Products of Combustion for One Pound of Coal Gas. Carbonic Acid. |
|---|---|---|---|---|---|---|---|---|---|---|
| | Per Cent. | Lbs. | Lbs. | Per Cent. | Thermal Units. | Thermal Units. | Lbs. | Lbs. | Lbs. | Lbs. |
| $CH_4$ . . | 37·34 | ·447 | ·01669 | 52·8 | 21510 | 11357 | 4 | 2·112 | 1·188 | 1·452 |
| $C_2H_4$, &c. . | 3·77 | ·1410 | ·00532 | 16·9 | 20100 | 3397 | $2\frac{4}{7}$ | ·579 | ·217 | ·531 |
| H . . . | 50·44 | ·00559 | ·00282 | 8·9 | 52200 | 4646 | 8 | ·712 | ·801 | ... |
| CO . . | 3·96 | ·0783 | ·00310 | 9·8 | 4350 | 426 | $\frac{4}{7}$ | ·056 | ... | ·154 |
| N . . . | 3·98 | ·0783 | ·00312 | 9·9 | ... | ... | ... | ... | ... | ... |
| $CO_2$ and O | ·51 | ·1060 | ·00054 | 1·7 | ... | ... | ... | ... | ... | ... |
| | 100·00 | ... | ·03159 | 100·0 | ... | 19826 | ... | 3·459 | 2·206 | 2·137 |

Calorific value of one cubic foot = 19826 × ·0316 = 626 thermal units.
" one pound = 19800 thermal units.

## Weight of Coal.

| | Per Cubic Foot, Solid. | Per Cubic Foot, Heaped. | Cubic Feet in One Ton, Heaped. |
|---|---|---|---|
| Anthracite | 85·4 lbs. | 58·3 lbs. | 38·4 cubic feet. |
| Bituminous | 78·3 „ | 49·8 „ | 45·3 „ |
| Cannel | 76·8 „ | 48·3 „ | 43·4 „ |

TABLE 310.—CALORIFIC VALUE OF COAL GAS.

(T. L. Miller.)

| Place of Manufacture. | Heating Power per Cubic Foot. |
|---|---|
| | Heat-Units. |
| Glasgow | 813 |
| Liverpool | 770 |
| Kilmarnock | 680 |
| Manchester | 654 |
| Birmingham | 639 |
| London | 624 |
| Hoboken | 617 |
| Berlin | 549 |

## Weight of Lime.

| | | | | |
|---|---|---|---|---|
| 1 bushel of quicklime weighs about | | | | 70 lbs. |
| 1 cubic foot | „ | „ | „ | 54 „ |
| 1 cubic yard | „ | „ | „ | 1460 „ |
| 1 ton | „ | measures about 32 bushels. | | |

Area of pipe-surface required for condensation of gas—10 square feet per 1000 cubic feet of maximum production per day of 24 hours (*Newbigging*).

## Illuminating Power of Gas.

The standard for comparison of gases for illuminating power is the sperm candle, weighing six to the pound, each burning off at the rate of 120 grains of sperm per hour. The gas for comparison is burned at the rate of 5 cubic feet per hour.

The gas supplied in London averages more than 16 candles for illuminating power. In fact, the larger companies are required, by Acts of Parliament, to supply gas of such a quality, that when burned through the Government standard Argand burner at the rate of 5 cubic feet per hour, it shall be capable of giving a light equal to that of 16 spermaceti candles, of six to the pound, when each candle is burning at

the rate of 120 grains of material per hour. This is called common gas. The London companies, and most provincial companies, are required to maintain in all their street mains a pressure equal to a column of water 1 inch in height, between sunset and midnight; and a pressure of $\frac{6}{10}$ inch between midnight and sunset.

## Main Pipes.

Main pipes should be tested to 150 feet of water pressure.

Cast-iron pipes below 3 inches bore, are made in lengths of 6 feet; from 3 inches to 11 inches, 9 feet long; 12 inches and upwards, 6 feet or 9 feet long.

The weight of cast-iron pipes is given by the formula, —

$$W = 2{\cdot}45\,(D^2 - d^2) \quad . \quad . \quad . \quad (1)$$

$D$ = diameter, outside, in inches.
$d$ = diameter inside, in inches.
$W$ = weight in pounds per lineal foot.

The weight of a socket is equal to $\frac{9}{10}$ths of that of a lineal foot of the pipe.

TABLE 311.—THICKNESS OF CAST-IRON GAS MAIN PIPES.

| Diameters. | Thickness. | Diameters. | Thickness. | Diameters. | Thickness. |
|---|---|---|---|---|---|
| Inches. | Inches. | Inches. | Inches. | Inches. | Inches. |
| 1, $1\frac{1}{2}$, 2 | $\frac{5}{16}$ | 12, 13, 14, 15 | $\frac{5}{8}$ | 30 | 1 |
| $2\frac{1}{2}$, 3, 4 | $\frac{3}{8}$ | 16, 17, 18 | $\frac{11}{16}$ | 36 | $1\frac{1}{8}$ |
| 5, 6 | $\frac{7}{16}$ | 19, 20, 21 | $\frac{3}{4}$ | 42 | $1\frac{3}{16}$ |
| 7, 8, 9 | $\frac{1}{2}$ | 22, 23 | $\frac{13}{16}$ | 48 | $1\frac{1}{4}$ |
| 10, 11 | $\frac{9}{16}$ | 24 | $\frac{7}{8}$ | | |

TABLE 312.—THICKNESS AND WEIGHT OF WROUGHT-IRON GAS PIPES.

| Diameter. | Thickness. | Weight per Lineal Foot. |
|---|---|---|
| Inches. | Inch. | Pounds. |
| 3, $3\frac{1}{2}$ | $\frac{5}{32}$ full | 6, 7 |
| 4, 5, 6 | $\frac{3}{16}$ | 9, $10\frac{1}{2}$, 13 |
| 7, 8, 9 | $\frac{1}{4}$ bare | 16, 20, $24\frac{1}{2}$ |
| 10, 12 | $\frac{1}{4}$ | 28, 33 |
| 14, 16 | $\frac{5}{16}$ | 43, 50 |

TABLE 313.—SMALL GAS-TUBES.

| Diameter Inside. | Light. | | Heavy. | |
|---|---|---|---|---|
| | Weight per Yard. | Length of Bundles. | Weight per Yard. | Length of Bundles. |
| Inches. | Lbs. Oz. | Yards. | Lbs. Oz. | Yards. |
| $\frac{1}{4}$ | 0 $11\frac{1}{2}$ | 80 | 0 15 | 67 |
| $\frac{3}{8}$ | 1 2 | 60 | 1 $6\frac{1}{2}$ | 46 |
| $\frac{1}{2}$ | 2 0 | 32 | 2 10 | 16 |
| $\frac{5}{8}$ | 2 4 | 25 | 3 0 | 20 |
| $\frac{3}{4}$ | 3 3 | 23 | 3 12 | 19 |
| 1 | 4 8 | 26 | 6 0 | 20 |
| $1\frac{1}{4}$ | 8 0 | 16 | 10 0 | 12 |
| $1\frac{1}{2}$ | 12 0 | 10 | 14 0 | 9 |
| 2 | 18 1 | 5 | 21 0 | 5 |

TABLE 314.—SMALL BRASS TUBES.

| Diameter Outside. | Weight per Foot. | Diameter Outside. | Weight per Foot. |
|---|---|---|---|
| Inches. | Pounds or Ounces. | Inches. | Pounds or Ounces. |
| $\frac{1}{4}$ | ·08 or 1·28 | $\frac{7}{8}$ | ·50 or 8·00 |
| $\frac{5}{16}$ | ·15 „ 2·40 | 1 | ·59 „ 9·44 |
| $\frac{3}{8}$ | ·19 „ 3·04 | $1\frac{1}{4}$ | ·81 „ 12·96 |
| $\frac{7}{16}$ | ·21 „ 3·36 | $1\frac{1}{2}$ | 1·00 „ 16·00 |
| $\frac{1}{2}$ | ·25 „ 4·00 | $1\frac{3}{4}$ | 1·12 „ 17·92 |
| $\frac{9}{16}$ | ·31 „ 4·96 | 2 | 1·25 „ 20·00 |
| $\frac{5}{8}$ | ·37 „ 5·92 | $2\frac{1}{2}$ | 1·50 „ 24·00 |
| $\frac{3}{4}$ | ·43 „ 6·88 | 3 | 1·87 „ 29·92 |

## Flow of Gas through Pipes.

Dr. Pole's formula for the volume of gas delivered through large pipes is as follows,—

$$Q = 1350\, d^2 \sqrt{\frac{hd}{sl}} \quad . \quad . \quad . \quad . \quad (2)$$

Conversely, the diameter of pipes required for a given rate of delivery, is,—

$$d = \sqrt[5]{\frac{Qsl}{(1350)^2 h}} \quad . \quad . \quad . \quad . \quad (3)$$

$Q$ = quantity of gas delivered, in cubic feet per hour.
$l$ = length of pipe, in yards.
$d$ = diameter of pipe, in inches.
$h$ = pressure in inches of water.
$s$ = specific gravity of gas = ·40 ; that of air being = 1.

For any other specific gravity, multiply the value of Q given by formula (2), by ·6325 (or $\sqrt{0·40}$), and divide the product by $\sqrt{\text{specific gravity}}$.

The discharge for small pipes is less than the calculated quantity. The value of *d* by formula (3) is to be augmented one-third for lead service pipes; and one-half for wrought-iron service pipes.

### Dowson Gas.

The Dowson gas is a cheap gas, generated by passing a mixture of superheated steam and air through a mass of red-hot carbonaceous fuel—anthracite by preference. The composition of the gas, generated with Garnant anthracite, as analysed by Professor William Foster, is as follows,—

| | Volume per cent. |
|---|---|
| Hydrogen | 18·73 |
| Marsh gas | ·31 |
| Olefiant gas | ·31 |
| Carbonic oxide | 25·07 |
| Carbonic acid | 6·57 |
| Oxygen | ·03 |
| Nitrogen | 48·98 |
| | 100·00 |

The calorific power of Dowson gas is about one-fourth of that of London gas. The anthracite fuel consumed per 1000 cubic feet is 13·2 pounds. Tested by D. K. Clark, in working an Otto gas engine developing 4·41 indicator horse-power, and 3·26 break horse-power, at a speed of 156 revolutions per minute, the following results were yielded :—

| | | | | | |
|---|---|---|---|---|---|
| Gas consumed | per | indicator | horse-power | 110·34 | cubic feet. |
| ,, | ,, | break | ,, | 149·30 | ,, |
| Fuel | ,, | indicator | ,, | 1·45 | lbs. |
| ,, | ,, | break | ,, | 1·97 | ,, |

The cost of Dowson gas is 50 per cent. less than that of coal-gas at 3*s*. per 1000 cubic feet. Whilst coal-gas of average composition requires chemically 5·3 volumes of air for combustion, each volume of Dowson gas requires only 1·1 volume of air.

More recently, Mr. Dowson has produced his gas from ordinary gas-coke. From the results of thirteen Otto engines, using Dowson gas, indicating from 150 to 16 horse-power, it appears that from 1·5 pounds to 1·2 pounds of fuel was consumed per indicator horse-power per hour.

TABLE 315.—OIL GAS, FROM BLUE PARAFFIN OIL.
(Macadam.)

| Items. | Pintsch's Apparatus. 1 | 2 | Mean | Keith's Apparatus. 1 | 2 | Mean |
|---|---|---|---|---|---|---|
| Specific gravity of oil . . . | ·878 | ·878 | ·878 | ·874 | ·878 | ·876 |
| Flashing point . . . . | 296° | 294° | 295° | 292° | 286° | 289° |
| Firing point . . . . . . | 356° | 352° | 354° | 348° | 346° | 347° |
| Gas per gallon, cubic feet . . | 90·7 | 103·4 | 97 | 85 | 84·8 | 84·9 |
| Illuminating power . . | 62·5 | 59·1 | 60·8 | 63·2 | 59·5 | 61·4 |
| Volume of oil in gallons, flowing in to each retort, per hour . . . . . . . | 1·4 | 1·18 | 1·29 | 2·3 | 1·3 | 1·8 |
| Gas per retort, per hour, cubic feet . . . . . . . | 126·8 | 122·5 | 124·6 | 197·5 | 111·9 | 154·7 |
| Heavy hydrocarbons, per cent. | 39·2 | 37·1 | 38·2 | 39·9 | 38·2 | 39·0 |
| Gas per ton, cubic feet . . | 23,138 | 26,356 | 24,742 | 21,772 | 21,671 | 21,721 |

TABLE 316.—PRODUCER GAS: COMPOSITION, BY WEIGHT.

| Elementary Gases. | H. Hydrogen. | CO. Carbonic Oxide. | $CO_2$. Carbonic Acid. | $CH_4$. Marsh Gas. | $C_2H_4$. Olefiant Gas. | N. |
|---|---|---|---|---|---|---|
| | Per cent. | Per cent. | Per cent. | Per cent. | Per cent. | Per cent. |
| Siemens Producer | ·00 | 24·92 | 6·95 | ·89 | 2·73 | 64·50 |
| ,, ,, | ·65 | 25·97 | 8·71 | 1·45 | ... | 63·22 |
| Wilson Producer . | ·90 | 29·58 | 6·91 | ·91 | ... | 61·70 |
| ,, ,, | 1·11 | 26·33 | 8·29 | 1·43 | ... | 62·84 |

## Gas Engines.

The Crossley gas engine, horizontal, is constructed with a single cylinder, of nominal powers of from ½ H.P. to 30 H.P., indicating from 2 H.P. to 85 H.P.: and with double cylinders of from 4 H.P. nominal to 30 H.P., indicating from 16 H.P. to 170 H.P. The over-all dimensions of the engine only, single cylinder, vary from 6 feet by 3 feet 7 inches, to 12 feet by 8 feet 2 inches. The speed of the engines is at the rate of 160 revolutions per minute, except for the ½ H.P. and the 1 H.P. engines, which make 180 per minute.

The 12 H.P. engine has developed 28 indicator H.P., and 23 H.P. at the break, or 82 per cent. of the indicator power; consuming 20 cubic feet of gas per indicator horse-power per hour, or 24·3 cubic feet per break horse-power. In a 4 H.P. engine, 23·3 cubic feet was consumed per break horse-power

The following Table 317, gives some results of trials of a Crossley gas engine.* The cylinder was 9½ inches in diameter, with a stroke of 18 inches; single-acting. The gas used was of the composition shown in Table 309.

TABLE 317.—CROSSLEY GAS ENGINE: RESULTS OF TRIALS.

| Trial. | A | B | C |
|---|---|---|---|
| Power | Full | Half | Empty |
| Revolutions per minute | 160·1 | 158·8 | 161·0 |
| Explosions per minute | 78·4 | 41·1 | 10·2 |
| Mean initial pressure . . Lbs. | 196·9 | 196·2 | 148·0 |
| Mean effective pressure . . ,, | 67·9 | 73·4 | 66·7 |
| Indicator horse-power . . H.-P. | 17·12 | 9·73 | 2·19 |
| Break horse-power . . ,, | 14·74 | 7·41 | ... |
| Mechanical efficiency . Per cent. | 86·1 | 76·2 | ... |
| Gas per hour, main . . Cub. ft. | 351·8 | 202·6 | 49·0 |
| ,, ,, for ignition . ,, | 3·5 | 3·2 | ... |
| ,, ,, total . . ,, | 355·3 | 205·8 | ... |
| Gas per indicator H.P. per hour, main, Cub. ft. | 20·55 | 20·8 | 22·38 |
| ,, ,, ,, total ,, | 20·76 | 21·2 | ... |
| Gas per break H.P. per hour, main ,, | 23·87 | 27·34 | ... |
| ,, ,, ,, total ,, | 24·10 | 27·77 | ... |
| Water for cooling per hour . . Lbs. | 713 | 480 | ... |
| Rise of temperature . . Fahr. | 128°·0 | 102°·3 | ... |
| Power to drive engine only . H.P. | 2·38 | 2·31 | 2·19 |
| Mean pressure during working stroke, equivalent to work done in pumping strokes . . . . Lbs. | 2·19 | ... | ... |
| Corresponding indicator . H.P. | ·55 | ... | ... |

The distribution of the heat of combustion of the gas in working the Crossley engine, was as follows,—

| Trial. | A. Per cent. | B. Per cent. | C. Per cent. |
|---|---|---|---|
| Heat turned into work | 22·1 | 20·9 | 19·4 |
| Heat rejected in jacket water | 43·2 | 41·1 | ... |
| Heat rejected in exhaust | 35·5 | 38·0 | ... |
| | 100·8 | 100·0 | ... |

* See *Report of the Judges on Trials of Motors for Electric Lighting*, 1889, for the Society of Arts.

TABLE 318.—RESULTS OF TRIALS OF GAS ENGINES. (T. L. Miller.)

| Type of Engine. | Tested by | Indicator Horse-Power. | Break Horse-Power. | Gas per I. H. P. | Gas per B.H. P. | Heat Converted into Work. | Revolutions per Minute. | Speed of Piston per Minute. |
|---|---|---|---|---|---|---|---|---|
| | | I. H. P. | B. H. P. | Cub. Feet. | Cub. Feet. | Per cent. | Turns. | Feet. |
| Otto | Adams | 3·42 | 2·87 | 30·9 | 33·4 | 14·46 | 160·3 | 320·6 |
| ,, | ,, | 22·56 | 18·31 | 23·6 | 29·1 | 17·5 | 158·7 | 423·2 |
| ,, | ,, | 33·6 | 27·75 | 25·04 | 30·3 | 16·15 | 151·37 | 529·7 |
| ,, | Society of Arts | 17·12 | 14·75 | 20·55 | 23·87 | 21·2 | 160·1 | 480·3 |
| Clerk | Garrett | 3·62 | 2·70 | 29·8 | 40 | 10·5 | 212 | 308 |
| ,, | ,, | 9·05 | 7·23 | 24·3 | 30·42 | 12·9 | 146 | 292 |
| ,, | ,, | 27·46 | 23·21 | 20·39 | 24·12 | 15·5 | 132 | 440 |
| Beck | Kennedy | 7·35 | 5·71 | 21·18 | 27·27 | 20·7 | 212 | 530 |
| ,, | ,, | 6·12 | 4·84 | 20·67 | 26·14 | 21·1 | 168·9 | 422·8 |
| Griffin | Jamieson | 17·28 | 13·6 | 19·27 | 24·48 | 20·8 | 183 | 427 |
| ,, | Kennedy | 17·46 | 14·94 | 18·92 | 23·58 | 21·2 | 223·8 | 522 |
| ,, | Society of Arts | 15·47 | 12·51 | 22·64 | 28 | 19·2 | 198·1 | 420·5 |
| Simplex | Witz | ... | 6·70 | ... | 21·55 | 19·4 | 160 | 420 |
| ,, | ,, | ... | 8·67 | ... | 20·12 | 20·9 | 160 | 420 |
| Forward | R. H. Smith | 5·54 | 4·807 | 20·79 | 23·97 | 19·2 | ... | ... |
| Ajax | Jamieson | 10·04 | 8·84 | 18·9 | 21·5 | ... | ... | ... |
| Fawcett | Miller | 11·49 | 8·52 | 18·4 | 24·74 | 19·6 | ... | ... |
| Atkinson | Unwin | 5·536 | 4·889 | 19·78 | 22·51 | 21·9 | ... | ... |
| ,, | Society of Arts | 11·15 | 9·48 | 19·22 | 22·61 | 22·8 | ... | ... |
| Hargreaves | Bird | 40 | tar or creosote | tar or creosote | ... | 31·4 | ... | ... |
| ,, | ,, | 5·17 | ,, | ,, | ... | 14·4 | ... | ... |

A Griffin gas engine, double-acting, was similarly tested. The cylinder was 9·02 inches in diameter, with a stroke of 14 inches. Three trials were made at full power, half power, and empty.

| Trial. | A. Per cent. | B. Per cent. | C. Per cent. |
|---|---|---|---|
| Heat turned into work | 21·1 | 19·4 | 17·5 |
| Heat rejected in jacket water | 35·2 | 32·5 | ... |
| Heat rejected in exhaust | 39·8 | 48·1 | ... |
| Unaccounted for, including heat rejected in blank charge of air | 3·9 | | |

## Oil Engines.

Oil engines are in considerable employment as oil motors. In the Priestman oil engine, mineral oil or petroleum is used, having a specific gravity of ·800 or upwards, with a flashing point from 75° to 150°. The oil is mixed with air under pressure, is drawn into the cylinder, and ignited by an electric spark from a small ordinary battery. The consumption of oil varies from about 1·25 pints or 1¼ pounds per break horse-power per hour for the larger engines, to 1·60 pints or 1·60 pounds for the smaller engines. An engine having an 8½-inch cylinder, with a 12-inch stroke, made 180 revolutions per minute, and developed 4·60 break horse-power, with a consumption of 1·20 pints or 1·20 pounds of oil per horse-power per hour. In a half-power trial, 2·36 break horse-power was developed on a consumption of 1·20 pints or 1·20 pounds of oil.

The Hargreaves motor is designed for burning coal-tar or creosote as fuel. It consists of an air-compressing pump and motor cylinder, to the latter of which a regenerator is adapted, which absorbs a portion of the heat of the exhaust gases, and yields it up to the incoming charge. The compressed-air is delivered through the regenerator into the motor cylinder, where it meets a jet of coal-tar or creosote, and, being heated to redness, ignites the fuel. Results of trials are given in Table 318 (p. 577), by Mr. Miller, who gives results of other trials, in one of which, a net power of 40 indicator H.P. was generated, by the consumption of ·512 pounds of coal-tar per indicator horse-power per hour. In another trial, with a smaller engine, for a net indicator power of 5·17 H.P., 1·2 pounds of creosote were consumed per indicator horse-power per hour.

## AIR IN MOTION.

DR. HUTTON'S statement of the law of resistance of air to bodies in motion, has been corroborated. It is that in the case of slow motion, the resistance is nearly as the square of the velocity; gradually increasing more and more above that proportion as the velocity increases.

### TABLE 319.—RESISTANCE OF AIR TO FLAT VANES, SQUARE AND ROUND.

(Fairweather.)

| Size. | Area. | Speed in Feet per Second. | | | | | |
|---|---|---|---|---|---|---|---|
| | | 5 | 10 | 15 | 20 | 25 | 30 |
| Inches. | Sq. Ft. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. |
| SQUARE. | | | | | | | |
| 7·41 | ·38 | ·55 | 1·4 | 3·25 | 5·7 | 9·4 | 14·0 |
| 12·9 | 1·155 | 1·30 | 5·5 | 13·60 | ... | ... | ... |
| 15·58 | 2·40 | 3·25 | 15·0 | ... | ... | ... | ... |
| CIRCLE. | | | | | | | |
| 7·24 | ·286 | ·30 | 1·15 | 2·6 | 4·6 | 7·4 | 10·9 |
| 12·65 | ·875 | ·85 | 3·85 | 9·1 | 16·4 | ... | ... |
| 18·36 | 1·840 | 2·40 | 10·00 | ... | ... | ... | ... |

### High Winds.

Empirical formula for the velocity and pressure of high winds:—

$$P=\frac{V^2}{10} \qquad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

$$V=\sqrt{10P} \qquad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

$V$ = maximum run of wind in any one hour.

$P$ = maximum pressure, in pounds per square foot, at any time during the storm, to which $V$ refers.

The formula (1) represents very fairly the greatest pressure as deduced from the mean velocity for an hour. The following are the greatest recorded pressures of wind per square foot at various places:—

| | Per Square Foot. | | Per Square Foot. |
|---|---|---|---|
| Aberdeen | 41 Lbs. | Liverpool | 90 Lbs. |
| Armagh | 27 " | London | 20·2 " |
| Birmingham | 27 " | Valentia | 65·6 " |
| Edinburgh | 35 " | Yarmouth | 42·2 " |
| Falmouth | 53·7 " | Brussels | 22 " |
| Glasgow | 47 " | Paris | 17 " |
| Greenwich | 42 " | Bombay | 38 " |
| Halifax | 30·2 " | Calcutta | 40 " |
| Holyhead | 64 " | Madras | 34 " |
| Kew | 27 " | | |

The Committee appointed to investigate the question, recommended that a maximum wind-pressure of 56 lbs. per square foot, should be employed in calculations for railway bridges and viaducts.

## Flow of Air in Pipes.

Mr. Hawksley's formulæ for the flow of air through pipes, under small differences of pressure, are as follows :—

$$v = 396\sqrt{\frac{h\,d}{l}} \qquad (3)$$

$$h = \frac{l\,v^2}{156{,}800\,d} \qquad (4)$$

$v$ = velocity in feet per second.
$h$ = head, or drag, in inches of water.
$d$ = diameter of pipe, in feet.
$l$ = length of pipe, or other passage, in feet.
$c$ = perimeter, in feet.
$a$ = sectional area of pipe, or other passage, in square feet.
Q = Quantity of air discharged, in cubic feet per second.
H = effective horse-power required for net work of discharge of air.

## Flow of Air through Passages of any form of Section, as Shafts, Air-ways, and Tunnels.

$$v = 796\sqrt{\frac{a\,h}{c\,l}} \qquad (5)$$

$$h = \frac{v^2\,c\,l}{633{,}000\,a} \qquad (6)$$

*Quantity of Air delivered per Second.*

From a pipe, $Q = 311 \sqrt{\frac{h\, d^5}{l}}$ . (7)

From a passage of any section, $Q = 796 \sqrt{\frac{a^3\, h}{c\, l}}$ . (8)

The density of dry air at 62° F., is taken at $\frac{1}{813}$ part of the density of water at 62·4 pounds per cubic foot; and 1 inch of water as equivalent to a pressure of 5·20 lbs. per square foot.

**Effective Horse-power for net work of Discharge of Air.**

From a pipe, $H = \frac{v\, d^2\, h}{135}$ . . . (9)

" $H = \frac{v^3\, d^2\, l}{21{,}200{,}000}$ . . (10)

from a passage of any section, $H = \frac{v\, a\, h}{106} = \frac{Q\, h}{106}$ . (11)

" " " $H = \frac{v^3\, c\, l}{67{,}000{,}000}$ . (12)

**Natural Flow of Air in Shafts of Mines.**

Mr. Hawksley's formula for the velocity of air in the up-cast shaft of a mine, due to difference of temperature is:—

$$v = 96 \sqrt{\frac{\frac{(T - t)}{(T + 448)} D\, s}{m\, l + 368\, s}} \quad . \quad . \quad (13)$$

$T$ = temperature of air in up-cast shaft (Fahr.).
$t$ = temperature of air in down-cast shaft.
$D$ = depth of shaft, in feet.
$m$ = periphery of air course, in feet.
$s$ = section of air-course, in square feet.
$l$ = length traversed by the current, in feet.
$v$ = velocity of current, in feet per second.

**Fans.—Ventilators.**

The following Table 320, of the most suitable dimensions of fans, is based on the results of Mr. Buckle's experiments. The case is of the form of an arithmetical spiral, widening the clear space between the case and the revolving blades, circumferentially, from the origin to the opening for discharge.

## TABLE 320.—DIMENSIONS OF FANS.

Pressure from 3 ounces to 6 ounces per square inch ; or 5·2 inches to 10·4 inches of water.

| Diameter of Fan. | Vanes. Width. | Vanes. Length. | Diameter of Inlet Openings. | Diameter of Fan. | Vanes. Width. | Vanes. Length. | Diameter of Inlet Openings. |
|---|---|---|---|---|---|---|---|
| Ft. Ins. | Ft. Ins. | Ft. Ins. | Ft. Ins. | Ft. Ins. | Ft. Ins. | Ft. Ins. | Ft. Ins. |
| 3 0 | 0 9 | 0 9 | 1 6 | 4 6 | 1 1½ | 1 1½ | 2 3 |
| 3 6 | 0 10½ | 0 10½ | 1 9 | 5 0 | 1 3 | 1 3 | 2 6 |
| 4 0 | 1 0 | 1 0 | 2 0 | 6 0 | 1 6 | 1 6 | 3 0 |
| Pressure, from 6 ounces to 9 ounces per square inch, and upwards, or 10·4 inches to 15·6 inches of water. | | | | | | | |
| 3 0 | 0 7 | 1 0 | 1 0 | 4 6 | 0 10½ | 1 4½ | 1 9 |
| 3 6 | 0 8½ | 1 1½ | 1 3 | 5 0 | 1 0 | 1 6 | 2 0 |
| 4 0 | 0 9½ | 1 3½ | 1 6 | 6 0 | 1 2 | 1 10 | 2 4 |

Guibal's fan, for mine ventilation, has blades which are straight, except at the outer ends, which curve forwards. The blades are fixed at a back inclination,—usually 45°—to the radius. The wheel is closely surrounded, for about two-thirds of the circumference, by a casing of brickwork. For the remaining third, the casing gradually opens out into the discharge vent, which expands upwards as an inverted frustum of a cone. A Guibal fan working at Staveley colliery, is 30 feet in diameter, 10 feet wide, it makes 60 revolutions per minute, with the following results of performance :—

| Speed in Turns per Minute. | Draft in Inches of Water. | Volume of Air Discharged per Minute. | Efficiency, in parts of the Gross Indicator Power of the Engine. |
|---|---|---|---|
| Turns. | Inches. | Cubic Feet. | Per cent. |
| 32 | ·70 | 43,852 | 40·4 |
| 51 | 1·70 | 86,283 | 43·1 |
| 64 | 2·77 | 101,773 | 53·3 |
| 68 | 3·10 | 110,005 | 53·8 |

# COMPRESSED AIR.

## Compressed or Expanded Isothermally.

Air when compressed or expanded under a uniform temperature, or isothermally, follows the hyperbolic law, according to which the pressure varies inversely as the volume.

The total net work for one stroke of the compressor of dry atmospheric air, isothermally, is found by the formula :—

$$W = P\,(V + v)\ \text{hyp. log.}\ \frac{V + v}{V' + v} - (P' - P)\,v \quad . \qquad (1)$$

The total net work of dry air for one stroke of a compressed air engine isothermally expanded in the cylinder down to atmospheric pressure, is given by formula :—

$$W = P\,(V + v)\ \text{hyp. log.}\ \frac{V' + v}{V + v} - (P - P')\,v \quad . \qquad (2)$$

The formulas (1) and (2) are identical in construction.

In cases where the back pressure $P''$ is less than $P'$, the terminal positive pressure, the total net work is given by formula :—

$$W = P\,(V + v)\ \text{hyp. log.}\ \frac{V' + v}{V + v} - P''\,V' + P\,V \,. \qquad (3)$$

$P$ = total pressure of air, in pounds per square foot.

$V$ = volume of air, in cubic feet.

$v$ = volume of clearance at each end of cylinder, in cubic feet.

$W$ = work done, in foot pounds.

In practice, the temperature is not uniform, but rises with compression, and falls with expansion : requiring more work for compression, and less work by expansion, than are provided in the above formulas. But these differences are minimised by the application of cooling agents, as cold water surrounding the working cylinder.

In compressing dry air at 62° F. in a non-conducting vessel, adiabatically, to two atmospheres of pressure, the temperature is raised to 178° F. ; and the fall to 62°, in a reservoir, involves a loss of 116°, which is a loss of 18 per cent. of the maximum absolute temperature, or 18 per cent. of efficiency for work.

## Table 321.—Pressure and Volume of Compressed Air. (Adapted from Mr. Shone's Table.)

| Pressure above Atmosphere. | | | Comparative Volume of Air after Compression. Initial Volume=1. | | Temperature by Adiabatic Compression, that of the Free Air being 60° F. | Rate of Compression Isothermally. | Average Load against Compressing Piston, per Square Inch. | |
|---|---|---|---|---|---|---|---|---|
| | | | Isothermally. | Adiabatically. | | | Isothermally. | Adiabatically. |
| Lbs. per Sq. In. | Inches of Mercury. | Feet of Water. | Volume. | Volume. | Fahr. | Compression. | Load. | Load. |
| 1 | 2·041 | 2·31 | 0·936 | 0·954 | 70·04 | 1·0680 | 0·967 | 0·976 |
| 2 | 4·082 | 4·61 | 0·880 | 0·913 | 79·64 | 1·1361 | 1·876 | 1·910 |
| 3 | 6·123 | 6·92 | 0·831 | 0·876 | 88·84 | 1·2041 | 2·730 | 2·805 |
| 4 | 8·164 | 9·23 | 0·786 | 0·843 | 97·68 | 1·2721 | 3·538 | 3·664 |
| 5 | 10·205 | 11·54 | 0·746 | 0·812 | 106·18 | 1·3401 | 5·303 | 4·491 |
| 6 | 12·246 | 13·84 | 0·710 | 0·784 | 114·39 | 1·4081 | 5·031 | 5·288 |
| 7 | 14·287 | 16·15 | 0·677 | 0·758 | 122·32 | 1·4762 | 5·725 | 6·060 |
| 8 | 16·328 | 18·46 | 0·648 | 0·735 | 129·99 | 1·5442 | 6·387 | 6·806 |
| 9 | 18·369 | 20·76 | 0·620 | 0·713 | 137·43 | 1·6122 | 7·021 | 7·529 |
| 10 | 20·410 | 23·07 | 0·595 | 0·692 | 144·65 | 1·6803 | 7·629 | 8·232 |
| 11 | 22·451 | 25·38 | 0·572 | 0·673 | 151·66 | 1·7483 | 8·212 | 8·914 |
| 12 | 24·492 | 27·68 | 0·551 | 0·655 | 158·48 | 1·8164 | 8·774 | 9·578 |
| 13 | 26·533 | 29·99 | 0·531 | 0·638 | 165·13 | 1·8844 | 9·315 | 10·224 |
| 14 | 28·574 | 32·30 | 0·512 | 0·622 | 171·60 | 1·9524 | 9·836 | 10·854 |
| 15 | 30·615 | 34·61 | 0·495 | 0·607 | 177·92 | 2·0204 | 10·338 | 11·468 |
| 16 | 32·656 | 36·91 | 0·479 | 0·593 | 184·09 | 2·0884 | 10·825 | 12·068 |
| 17 | 34·697 | 39·22 | 0·464 | 0·579 | 190·11 | 2·1565 | 11·297 | 12·654 |
| 18 | 36·738 | 41·53 | 0·450 | 0·567 | 196·01 | 2·2245 | 11·753 | 13·227 |
| 19 | 38·779 | 43·83 | 0·436 | 0·555 | 201·77 | 2·2925 | 12·193 | 13·788 |
| 20 | 40·820 | 46·14 | 0·424 | 0·544 | 207·42 | 2·3605 | 12·623 | 14·337 |
| 21 | 42·861 | 48·45 | 0·412 | 0·533 | 212·95 | 2·4286 | 13·044 | 14·875 |
| 22 | 44·902 | 50·75 | 0·401 | 0·522 | 218·37 | 2·4966 | 13·450 | 15·403 |
| 23 | 46·943 | 53·06 | 0·390 | 0·512 | 223·69 | 2·5646 | 13·844 | 15·921 |
| 24 | 48·984 | 55·37 | 0·380 | 0·503 | 228·91 | 2·6327 | 14·230 | 16·429 |
| 25 | 51·025 | 57·68 | 0·370 | 0·494 | 234·03 | 2·7007 | 14·604 | 16·927 |
| 26 | 53·066 | 59·98 | 0·361 | 0·485 | 239·07 | 2·7687 | 14·970 | 17·419 |
| 27 | 55·107 | 62·29 | 0·353 | 0·477 | 244·02 | 2·8367 | 15·327 | 17·898 |
| 28 | 57·148 | 64·60 | 0·344 | 0·469 | 248·88 | 2·9048 | 15·676 | 18·371 |
| 29 | 59·189 | 66·90 | 0·336 | 0·461 | 253·66 | 2·9728 | 16·016 | 18·837 |
| 30 | 61·230 | 69·21 | 0·329 | 0·454 | 258·37 | 3·0408 | 16·348 | 19·294 |
| 31 | 63·271 | 71·52 | 0·322 | 0·447 | 263·00 | 3·1088 | 16·673 | 19·745 |
| 32 | 65·312 | 73·82 | 0·315 | 0·440 | 267·56 | 3·1769 | 16·992 | 20·190 |
| 33 | 67·353 | 76·13 | 0·308 | 0·434 | 272·05 | 3·2449 | 17·303 | 20·626 |
| 34 | 69·394 | 78·44 | 0·302 | 0·427 | 276·48 | 3·3129 | 17·608 | 21·056 |
| 35 | 71·435 | 80·75 | 0·296 | 0·421 | 280·84 | 3·3810 | 17·907 | 21·480 |
| 36 | 73·476 | 83·05 | 0·290 | 0·415 | 285·14 | 3·4490 | 18·200 | 21·899 |
| 37 | 75·517 | 85·36 | 0·284 | 0·409 | 289·38 | 3·5170 | 18·487 | 22·312 |
| 38 | 77·558 | 87·67 | 0·279 | 0·404 | 293·56 | 3·5850 | 18·768 | 22·718 |
| 39 | 79·599 | 89·97 | 0.274 | 0·399 | 297·68 | 3·6531 | 19·045 | 23·121 |
| 40 | 81·640 | 92·28 | 0·269 | 0·393 | 301·75 | 3·7211 | 19·316 | 23·516 |
| 41 | 83·681 | 94·59 | 0·264 | 0·388 | 305·77 | 3·7891 | 19·581 | 23·908 |
| 42 | 85·722 | 96·89 | 0·259 | 0·383 | 309·74 | 3·8571 | 19·844 | 24·293 |
| 43 | 87·763 | 99·20 | 0·255 | 0·379 | 313·66 | 3·9252 | 20·101 | 24·675 |
| 44 | 89·804 | 101·51 | 0·250 | 0·374 | 317·53 | 3·9932 | 20·353 | 25·052 |
| 45 | 91·845 | 103·82 | 0·246 | 0·370 | 321·36 | 4·0612 | 20·602 | 25·424 |
| 46 | 93·686 | 106·12 | 0·242 | 0·365 | 325·13 | 4·1293 | 20·846 | 25·729 |
| 47 | 95·927 | 108·43 | 0·238 | 0·361 | 328·87 | 4·1973 | 21·086 | 26·155 |
| 48 | 97·968 | 110·74 | 0·234 | 0·357 | 332·56 | 4·2653 | 21·323 | 26·515 |
| 49 | 100·009 | 113·04 | 0·231 | 0·353 | 336·21 | 4·3333 | 21·555 | 26·870 |
| 50 | 102·050 | 115·35 | 0·227 | 0·349 | 339·82 | 4·4014 | 21·784 | 27·221 |

The following table shows the corresponding loss of efficiency for several pressures :—

TABLE 322.—LOSS OF EFFICIENCY OF COMPRESSED AIR.

| Pressure. | Final Temperature for Compression. | Reduced Efficiency, Initial Temperature for Work, 62° F. | Loss of Efficiency. |
|---|---|---|---|
| Atmospheres. | ° Fahr. | Per cent. | Per cent. |
| 2 | 178 | 82 | 18 |
| 3 | 258 | 73 | 27 |
| 4 | 321 | 67 | 33 |
| 5 | 373 | 63 | 37 |
| 10 | 559 | 51 | 49 |

Taking the efficiency of the compressor, and also that of the power-engine, at 80 per cent., the resultant efficiency of the combined compressor and engine, working to 10 atmospheres is $\left(\frac{80 \times 80}{100} \times 51 =\right)$ 33 per cent. Working to two atmospheres, the resultant efficiency is 52 per cent. In general practice, the resultant efficiency rarely exceeds 30 per cent.

Table 321 shows the relation of pressure, volume, and temperature, with the load against a compressing piston.

Table 323 shows the net horse-power required for compressing atmospheric air, under pressures of from 2 to 20 atmospheres, calculated by means of formula (1); on the assumption that the temperature is maintained uniformly at 62° F.

The same table shows, reversely, the horse-power developed by compressed air introduced into the cylinder at the various pressures; on the assumption that the temperature is uniformly 62° F., and that the air is expanded down to atmospheric pressure at the end of the stroke. But, when the air is exhausted, at a pressure higher than that of the atmosphere, the difference of the initial work P V and the work of back pressure, $P'' V'$, is to be added to the work as calculated by formula (3).

### Flow of Compressed Air through Pipes.

The head, or difference of the pressures at the beginning and end of a long pipe, through which compressed air is forced, may be taken to vary as the length of the pipe, as the square of the velocity, and inversely as the diameter. According to some authorities, it varies also with the density of the air; according to others it does not so vary. In Table 324 are given the results of observations made on the flow of compressed a[illegible] in pipes at the St. Gothard tunnel.

TABLE 323.—NET POWER REQUIRED TO COMPRESS AIR AT THE UNIFORM TEMPERATURE 62° F.

| Atmospheres of Pressure, and Ratio of Expansion. 1 Atmosphere = 1. | | Pressure per Square Inch (approximate). | Horse Power per Cubic Foot of Compressed Air per Minute. | Volume of Compressed Air per Minute per Horse Power, at 62° F. | Equivalent Volume of Free Air, under one Atmosphere, at 62° F. |
|---|---|---|---|---|---|
| | Hyperbolic Logarithm of Ratio of Expansion. | Lbs. | H. P. | Cubic Feet. | Cubic Feet. |
| 2 | ·6931 | 30 | ·0889 | 11·25 | 22·50 |
| 3 | 1·0986 | 45 | ·2114 | 4·73 | 14·19 |
| 4 | 1·3863 | 60 | ·3556 | 2·88 | 11·52 |
| 5 | 1·6094 | 75 | ·516 | 1·94 | 9·70 |
| 6 | 1·7918 | 90 | ·690 | 1·450 | 8·70 |
| 7 | 1·9459 | 105 | ·874 | 1·145 | 8·01 |
| 8 | 2·0794 | 120 | 1·067 | ·938 | 7·50 |
| 9 | 2·1972 | 135 | 1·268 | ·788 | 7·09 |
| 10 | 2·3026 | 150 | 1·477 | ·667 | 6·67 |
| 11 | 2·3979 | 165 | 1·692 | ·591 | 6·50 |
| 12 | 2·4849 | 180 | 1·913 | ·523 | 6·28 |
| 13 | 2·5649 | 195 | 2·139 | ·468 | 6·08 |
| 14 | 2·6391 | 210 | 2·369 | ·422 | 5·91 |
| 15 | 2·7084 | 225 | 2·606 | ·384 | 5·76 |
| 16 | 2·7726 | 240 | 2·845 | ·352 | 5·63 |
| 17 | 2·8332 | 255 | 3·089 | ·324 | 5·51 |
| 18 | 2·8904 | 270 | 3·336 | ·300 | 5·40 |
| 19 | 2·9444 | 285 | 3·587 | ·279 | 5·30 |
| 20 | 2·9957 | 300 | 3·843 | ·260 | 5·20 |

At the Mont Cenis tunnel, compressed air of 5·70 atmospheres of pressure was reduced to 5·50 atmospheres, or by $3\frac{1}{2}$ per cent. of the head, in a $7\frac{5}{8}$ inch cast-iron pipe 1775 yards in length, comprising leakage and frictional resistance; whilst 64 cubic feet of compressed air was delivered per minute. In a length of 6,666 yards of pipe, the loss was 5 per cent. of the initial pressure.

The Table 325 of loss of pressure by friction in pipes, has been issued by the Rand Drill Company. The calculated quantities are those for straight pipes. To make ample allowance for heads, elbows, and tees, one size of pipe larger than the tabular size may be taken.

TABLE 324.—LOSS OF PRESSURE IN COMPRESSED-AIR PIPE-MAIN, AT ST. GOTHARD TUNNEL.

(E. Stockalper.)

| Experiment. | Air Main. | | Volume per Second of Free Air, or Equivalent Volume at Atmospheric Pressure and 32° F. | Volume per Second of Compressed Air at Mean Density. | Mean Density of Compressed Air. (Water = 1) | Weight of Air Flowing per Second. | Mean Velocity in Feet per Second. | Mean Temperature in Main. | Observed Pressures. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Diameter. | Length. | | | | | | | Pressure at Beginning of Pipe. | Pressure at End of Pipe. | Loss of Pressure. | |
| No. | Inches. | Feet. | Cubic Feet. | Cub. Ft. | Density. | Lbs. | Feet. | Fahr. | Atmos. | Atmos. | Atmos. | Per Cent. |
| 1 | 7·87 | 15,092 | 33·056 | 6·534 | ·00650 | 2·669 | 19·32 | 70 | 5·60 | 5·24 | 0·36 | 6·4 |
| | 5·91 | 1,712·6 | | 7·063 | ·00603 | 2·669 | 37·14 | 80 | 5·24 | 5·00 | 0·24 | 4·6 |
| 2 | 7·87 | 15,092 | 22·002 | 5·509 | ·00514 | 1·776 | 16·30 | 70 | 4·35 | 4·13 | 0·22 | 5·1 |
| | 5·91 | 1,712·6 | | 5·863 | ·00482 | 1·776 | ... | 80 | 4·13 | ... | ... | ... |
| 3 | 7·87 | 15,042 | 18·364 | 5·262 | ·00449 | 1·483 | 15·58 | 70 | 3·84 | 3·65 | 0·19 | 5·0 |
| | 5·91 | 1,712·6 | | 5·580 | ·00423 | 1·483 | 29·34 | 80 | 3·65 | 3·54 | 0·11 | 3·0 |

## TABLE 325.—LOSS OF PRESSURE BY FRICTION OF COMPRESSED AIR IN PIPES.

(F. A. Halsey.)

| Diameter of Pipe. | Cubic Feet of Free Air compressed to a Gauge Pressure of 60 lbs. per Square Inch, and passing through the Pipe per Minute. | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 50 | 75 | 100 | 125 | 150 | 200 | 250 | 300 | 400 | 600 | 800 | 1000 | 1200 | 1500 | 1800 | 2000 | 2500 | 3000 | 4000 | 5000 |
| | Loss of Pressure in Pounds per Square Inch for each 1,000 Feet of Straight Pipe. | | | | | | | | | | | | | | | | | | | |
| Ins. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. |
| 1 | 10·40 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| $1\frac{1}{4}$ | 2·63 | 5·90 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| $1\frac{1}{2}$ | 1·22 | 2·75 | 4·89 | 7·65 | 11·00 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| 2 | ·35 | ·79 | 1·41 | 2·20 | 3·17 | 5·64 | 8·78 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| $2\frac{1}{2}$ | ·14 | ·32 | ·57 | ·90 | 1·29 | 2·30 | 3·58 | 5·18 | 9·20 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| 3 | ... | ·11 | ·20 | ·31 | ·44 | ·78 | 1·23 | 1·77 | 3·14 | 7·05 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| $3\frac{1}{2}$ | ... | ... | ... | ·15 | ·21 | ·38 | ·59 | ·85 | 1·51 | 3·40 | 6·03 | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| 4 | ... | ... | ... | ... | ... | ·20 | ·31 | ·45 | ·80 | 1·81 | 3·22 | 5·02 | 7·23 | 11·30 | ... | ... | ... | ... | ... | ... |
| 5 | ... | ... | ... | ... | ... | ... | ·10 | ·15 | ·26 | ·59 | 1·04 | 1·63 | 2·35 | 3·66 | 5·28 | 6·50 | 10·20 | ... | ... | ... |
| 6 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ·23 | ·41 | ·64 | ·93 | 1·46 | 2·09 | 2·59 | 4·06 | 5·81 | 10·30 | ... |
| 8 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ·10 | ·16 | ·23 | ·37 | ·53 | ·65 | 1·02 | 1·47 | 2·61 | 4·08 |
| 10 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ·12 | ·17 | ·21 | ·33 | ·47 | ·84 | 1·30 |
| 12 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ·13 | ·19 | ·34 | ·53 |
| 14 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ·16 | ·24 |

## REFRIGERATING MACHINERY.

For the cooling of brine and other liquids by the alternate compression and expansion of air, Mr. David Thomson gives the following formulæ, in which the machine is supposed to be perfect :—

$$P = 772\ C \times \frac{T - T'}{T'} \quad . \quad . \quad . \quad . \quad (1)$$

$$C = \frac{P}{772} \times \frac{T'}{T - T'} \quad . \quad . \quad . \quad . \quad (2)$$

P = power required to do the cooling work C, in foot-pounds.

C = cooling work done, in thermal units.

T = Absolute maximum temperature, Fahrt., of the air in the hot or compression end of the cooling machine.

T′ = absolute minimum temperature, Fahrt., of the air in the cold or expansion end of the machine.

These formulæ indicate that the most economical results, as regards consumption of power, are obtained when the machine is worked within a small range of temperature, as in breweries, where the temperature of water is frequently to be lowered only 10° F.

These formulæ are applicable to all cooling machines, whether they operate by means of air, ether, ammonia, or any other fluid.

In the ammonia machine, or other machine working on the same principle, in which no mechanical power is applied, the value of P, it is understood, is the heat theoretically required, at the rate of 1 heat-unit for 772 foot-pounds of power; and the formula (1) becomes :—

(Ammonia). Heat required to do the work $C = C\,\frac{T - T_1}{T_1}$ . (3)

The ammonia machine has, theoretically, a great economical superiority, as heat is so much less expensive than its equivalent of mechanical power.

The nature of the vapour employed affects the size of the machine ; the relative capacity of cylinder required being :—

| | | | |
|---|---|---|---|
| Ammonia | 1 | Methyl ether | 1·8 |
| Carbonic acid | 0·16 | Sulphurous acid | 2·6 |
| Methyl chloride | 1·8 | Ether | 15·1 |

## HOT-AIR ENGINES.

In Rider's Hot-air Engine, called a compression engine, two single-acting cylinders are placed vertically, side by side, connected at the upper part by a regenerator composed of thin plates. One of those is the working or hot cylinder, under which a fire is maintained; the other is the air-pump, or cold cylinder, surrounded by water to cool the air which is drawn into it, and which is pumped into the hot cylinder. The plungers of the cylinders are worked by cranks forming an angle of 95°, on a shelf overhead. The 1-horse-power engine has 6¾-inch plungers, with strokes of 9½ inches hot, and 8·6 inches cold. At a speed of 120 turns per minute, the effective mean pressure in the hot cylinder was 16·8 lbs. per square inch; and in the cold cylinder 7·15 lbs.; leaving 10·33 lbs. net effective pressure on the hot plunger, making 1·076 horse-power. It is stated that the coal consumed was at the rate of from 2lbs. to 3lbs. per net indicator horse-power.

In Benier's Hot-Air Engine, the air is heated within the working cylinder by means of a furnace within the cylinder. All the heat of combustion is directly utilised; the valves are only traversed by cold air; and the heated air acts directly as it expands on the piston. It is stated that the consumption of coke is at the rate of 3·3 pounds per horse-power per hour for motors of 4 horse-power; and 4 pounds for motors of 2 horse-power.

## WATER POWER.

### Flow of Water.

The flow of water by the action of gravity, if there be no deduction from the force, is according to the formula,—

$$v = 8\sqrt{h} \quad . \quad . \quad . \quad . \quad . \quad (1)$$

$v$ = velocity in feet per second.

$h$ = height of fall in feet.

The velocity of water discharged through the side of a vessel is variously affected by the form of the ajutage. In

parts of the theoretical velocity $v$, as above, the velocity varies thus :—

| | Per cent. |
|---|---|
| With internal tube . . . . . . . . . | 50 |
| Thin plate only . . . . . . . . . . | 62 |
| Nozzle, 2 diameters in length . . . . . | 82 |
| Converging cone, length $2\frac{1}{2}$ diameters. . . | 95 |
| Vena contracta, length $\frac{1}{2}$ diameter of orifice . Smallest diameter ·785 diameter of orifice | 160 |
| Diverging cone. length 9 diameters . . . | 146 |

The velocity of flow of water in a full smooth cast-iron pipe of uniform diameter, is given by the formula:—(Hawksley).

$$v = 48\sqrt{\frac{h}{l} \times d} \quad . \quad . \quad . \quad . \qquad (2)$$

Mr. Downing employs the same formula with the co-efficient 50 instead of 48. His formula for the quantity of water discharged from a channel or pipe is,—

$$Q = 100a\sqrt{\frac{h}{l} \times D} \quad . \quad . \quad . \quad . \qquad (3)$$

$v$ = velocity, in feet per second.
$h$ = head, in feet.
$l$ = length, in feet.
$d$ = diameter, in feet.
$c$ = wetted perimeter, in feet.
$a$ = sectional area of current, in square feet.
Q = quantity of water discharged, in cubic feet per second.
$D = \frac{a}{c}$ = hydraulic mean depth.

By the aid of Table 326, based on formula (3), the discharge, the diameter of pipe, and the fall are readily calculable.

1. *To find the rate of discharge*, when the length, fall, and diameter of pipe in feet are given. Divide the tabular number next the diameter by the square root of the rate of inclination. The quotient is the rate of discharge in cubic feet per minute.

2. *To find the required diameter*, when the length and fall in feet, and the rate of discharge in cubic feet per minute, are given. Multiply the rate of discharge by the square root of the rate of inclination; find the product or the nearest value to it in the table. The diameter next to it is the diameter required, in feet.

3. *To find the required fall*, when the length and diameter

in feet, and the rate of discharge in cubic feet per minute are given. Divide the tabular number next the given diameter by the rate of discharge ; square the quotient, and multiply it by the length of pipe. The final quotient is the fall in feet.

*Note.*—The rate of inclination is the quotient of the length by the vertical height.

Half the tabular number may be taken to find approximately the discharge for pipes half-full. The calculation is also available for sewers and the like.

TABLE 326.—DISCHARGE OF WATER IN PIPES.
(Turnbull.)

| Diameter of Pipes. | Tabular Number. | Diameter of Pipes. | Tabular Number | Diameter of Pipes. | Tabular Number. |
|---|---|---|---|---|---|
| Inches. | | Inches. | | Inches. | |
| 1 | 4·7 | 21 | 9544 | 42 | 53994 |
| 1½ | 13·0 | 22 | 10717 | 43 | 57250 |
| 2 | 26·4 | 23 | 11971 | 44 | 60625 |
| 3 | 73·6 | 24 | 13327 | 45 | 64142 |
| 4 | 150·7 | 25 | 14753 | 46 | 67770 |
| 5 | 262·9 | 26 | 16267 | 47 | 71494 |
| 6 | 416·5 | 27 | 17881 | 48 | 75391 |
| 7 | 611·4 | 28 | 19523 | 51 | 87713 |
| 8 | 852·8 | 29 | 21375 | 54 | 101190 |
| 9 | 1147·7 | 30 | 23282 | 57 | 115844 |
| 10 | 1492·1 | 31 | 25263 | 60 | 131700 |
| 11 | 1892 | 32 | 27335 | 66 | 167134 |
| 12 | 2356 | 33 | 29545 | 72 | 207752 |
| 13 | 2875 | 34 | 31826 | 78 | 253764 |
| 14 | 3459 | 35 | 34208 | 84 | 305384 |
| 15 | 4115 | 36 | 36726 | 90 | 362871 |
| 16 | 4806 | 37 | 39319 | 96 | 426436 |
| 17 | 5621 | 38 | 42018 | 102 | 496220 |
| 18 | 6492 | 39 | 44861 | 108 | 572343 |
| 19 | 7259 | 40 | 47674 | 114 | 655124 |
| 20 | 8439 | 41 | 58811 | 120 | 745014 |

**Discharge of Water through Fire-hose and Nozzles.**

In Tables 329 and 330, are given the actual discharge of water through small nozzles and ring-nozzles connected to 2½-inch hose, 50 feet and 100 feet long.

In Table 331, are given the loss of head by friction in fire-hose, of rubber and of leather, under given heads and rates of discharge.

TABLE 327.—PRESSURE OF WATER FOR GIVEN HEADS.

| Head. | Pressure per Square Inch. | Head. | Pressure per Square Inch. | Head. | Pressure per Square Inch. | Head. | Pressure per Square Inch. |
|---|---|---|---|---|---|---|---|
| Feet. | Pounds. | Feet. | Pounds. | Feet. | Pounds. | Feet. | Pounds. |
| 1 | 0·43 | 41 | 17·75 | 81 | 35·08 | 121 | 52·41 |
| 2 | 0·86 | 42 | 18·19 | 82 | 35·52 | 122 | 52·84 |
| 3 | 1·30 | 43 | 18·62 | 83 | 35·05 | 123 | 53·28 |
| 4 | 1·73 | 44 | 19·05 | 84 | 36·39 | 124 | 53·71 |
| 5 | 2·16 | 45 | 19·49 | 85 | 36·82 | 125 | 54·15 |
| 6 | 2·59 | 46 | 19·92 | 86 | 37·25 | 126 | 54·58 |
| 7 | 3·03 | 47 | 20·35 | 87 | 37·68 | 127 | 55·01 |
| 8 | 3·46 | 48 | 20·79 | 88 | 38·12 | 128 | 55·44 |
| 9 | 3·89 | 49 | 21·22 | 89 | 38·55 | 129 | 55·88 |
| 10 | 4·33 | 50 | 21·65 | 90 | 38·98 | 130 | 56·31 |
| 11 | 4·76 | 51 | 22·09 | 91 | 39·42 | 131 | 56·74 |
| 12 | 5·20 | 52 | 22·52 | 92 | 39·85 | 132 | 57·18 |
| 13 | 5·63 | 53 | 22·95 | 93 | 40·28 | 133 | 57·61 |
| 14 | 6·06 | 54 | 23·39 | 94 | 40·72 | 134 | 58·04 |
| 15 | 6·49 | 55 | 23·82 | 95 | 41·15 | 135 | 58·48 |
| 16 | 6·93 | 56 | 24·26 | 96 | 41·58 | 136 | 58·91 |
| 17 | 7·36 | 57 | 24·69 | 97 | 42·01 | 137 | 59·34 |
| 18 | 7·79 | 58 | 25·12 | 98 | 42·45 | 138 | 59·77 |
| 19 | 8·22 | 59 | 25·55 | 99 | 42·88 | 139 | 60·21 |
| 20 | 8·66 | 60 | 25·99 | 100 | 43·31 | 140 | 60·64 |
| 21 | 9·09 | 61 | 26·42 | 101 | 43·75 | 141 | 61·07 |
| 22 | 9·53 | 62 | 26·85 | 102 | 44·18 | 142 | 61·51 |
| 23 | 9·96 | 63 | 27·29 | 103 | 44·61 | 143 | 61·94 |
| 24 | 10·39 | 64 | 27·72 | 104 | 45·05 | 144 | 62·37 |
| 25 | 10·82 | 65 | 28·15 | 105 | 45·48 | 145 | 62·81 |
| 26 | 11·26 | 66 | 28·58 | 106 | 45·91 | 146 | 63·24 |
| 27 | 11·69 | 67 | 29·02 | 107 | 46·34 | 147 | 63·67 |
| 28 | 12·12 | 68 | 29·45 | 108 | 46·78 | 148 | 64·10 |
| 29 | 12·55 | 69 | 29·88 | 109 | 47·21 | 149 | 64·54 |
| 30 | 12·99 | 70 | 30·32 | 110 | 47·64 | 150 | 64·97 |
| 31 | 13·42 | 71 | 30·75 | 111 | 48·08 | 151 | 65·40 |
| 32 | 13·86 | 72 | 31·18 | 112 | 48·51 | 152 | 65·84 |
| 33 | 14·29 | 73 | 31·62 | 113 | 48·94 | 153 | 66·27 |
| 34 | 14·72 | 74 | 32·05 | 114 | 49·38 | 154 | 66·70 |
| 35 | 15·16 | 75 | 32·48 | 115 | 49·81 | 155 | 67·14 |
| 36 | 15·59 | 76 | 32·92 | 116 | 50·24 | 156 | 67·57 |
| 37 | 16·02 | 77 | 33·35 | 117 | 50·68 | 157 | 68·00 |
| 38 | 16·45 | 78 | 33·78 | 118 | 51·11 | 158 | 68·43 |
| 39 | 16·89 | 79 | 34·21 | 119 | 51·54 | 159 | 68·87 |
| 40 | 17·32 | 80 | 34·65 | 120 | 51·98 | 160 | 69·31 |

TABLE 327.—PRESSURE OF WATER FOR GIVEN HEADS (*continued*).

| Head. | Pressure per Square Inch. | Head. | Pressure per Square Inch. | Head. | Pressure per Square Inch. | Head. | Pressure per Square Inch. |
|---|---|---|---|---|---|---|---|
| Feet. | Pounds. | Feet. | Pounds. | Feet. | Pounds. | Feet. | Pounds. |
| 161 | 69·74 | 200 | 86·63 | 239 | 103·53 | 278 | 120·42 |
| 162 | 70·17 | 201 | 87·07 | 240 | 103·96 | 279 | 120·85 |
| 163 | 70·61 | 202 | 87·50 | 241 | 104·39 | 280 | 121·29 |
| 164 | 71·04 | 203 | 87·93 | 242 | 104·83 | 281 | 121·72 |
| 165 | 71·47 | 204 | 88·36 | 243 | 105·26 | 282 | 122·15 |
| 166 | 71·91 | 205 | 88·80 | 244 | 105·69 | 283 | 122·59 |
| 167 | 72·34 | 206 | 89·23 | 245 | 106·13 | 284 | 123·02 |
| 168 | 72·77 | 207 | 89·66 | 246 | 106·56 | 285 | 123·45 |
| 169 | 73·20 | 208 | 90·10 | 247 | 106·99 | 286 | 123·89 |
| 170 | 73·64 | 209 | 90·53 | 248 | 107·43 | 287 | 124·32 |
| 171 | 74·07 | 210 | 90·96 | 249 | 107·86 | 288 | 124·75 |
| 172 | 74·50 | 211 | 91·39 | 250 | 108·29 | 289 | 125·18 |
| 173 | 74·94 | 212 | 91·83 | 251 | 108·73 | 290 | 125·62 |
| 174 | 75·37 | 213 | 92·26 | 252 | 109·16 | 291 | 126·05 |
| 175 | 75·80 | 214 | 92·69 | 253 | 109·59 | 292 | 126·48 |
| 176 | 76·23 | 215 | 93·13 | 254 | 110·03 | 293 | 126·92 |
| 177 | 76·67 | 216 | 93·56 | 255 | 110·46 | 294 | 127·35 |
| 178 | 77·10 | 217 | 93·99 | 256 | 110·89 | 295 | 127·78 |
| 179 | 77·53 | 218 | 94·43 | 257 | 111·32 | 296 | 128·22 |
| 180 | 77·97 | 219 | 94·86 | 258 | 111·76 | 297 | 128·65 |
| 181 | 78·40 | 220 | 95·30 | 259 | 112·19 | 298 | 129·08 |
| 182 | 78·84 | 221 | 95·73 | 260 | 112·62 | 299 | 129·51 |
| 183 | 79·27 | 222 | 96·16 | 261 | 113·06 | 300 | 129·95 |
| 184 | 79·70 | 223 | 96·60 | 262 | 113·49 | 310 | 134·28 |
| 185 | 80·14 | 224 | 97·03 | 263 | 113·92 | 320 | 134·62 |
| 186 | 80·57 | 225 | 97·46 | 264 | 114·36 | 330 | 142·95 |
| 187 | 81·00 | 226 | 97·90 | 265 | 114·79 | 340 | 147·28 |
| 188 | 81·43 | 227 | 98·33 | 266 | 115·22 | 350 | 151·61 |
| 189 | 81·87 | 228 | 98·76 | 267 | 115·66 | 360 | 155·94 |
| 190 | 82·30 | 229 | 99·20 | 268 | 116·09 | 370 | 160·27 |
| 191 | 82·73 | 230 | 99·63 | 269 | 116·52 | 380 | 164·61 |
| 192 | 83·17 | 231 | 100·06 | 270 | 116·96 | 390 | 168·94 |
| 193 | 83·60 | 232 | 100·49 | 271 | 117·39 | 400 | 173·27 |
| 194 | 84·03 | 233 | 100·93 | 272 | 117·82 | 500 | 216·58 |
| 195 | 84·47 | 234 | 101·36 | 273 | 118·26 | 600 | 259·90 |
| 196 | 84·90 | 235 | 101·79 | 274 | 118·69 | 700 | 302·22 |
| 197 | 85·33 | 236 | 102·23 | 275 | 119·12 | 800 | 346·54 |
| 198 | 85·76 | 237 | 102·66 | 276 | 119·56 | 900 | 389·86 |
| 199 | 86·20 | 238 | 103·09 | 277 | 119·99 | 1000 | 433·18 |

TABLE 328.—FLOW OF WATER THROUGH CLEAN CAST-IRON PIPES, AND RELATIVE LOSS OF HEAD BY FRICTION, FOR EACH 100 FEET LENGTH OF PIPE. (Based on Ellis and Howland's experiments.)

| Velocity in Feet per Second. | Diameter of Pipes, in Inches. | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 3 | | 4 | | 5 | | 6 | | 7 | | 8 | | 9 | | 10 | | 12 | | 14 | |
| | Discharge per Minute in Cubic Feet, and Loss of Head in Feet, per 100 Feet long. | | | | | | | | | | | | | | | | | | | |
| Feet. | Cubic Feet. | Feet of Head. | Cubic Feet. | Feet of Head | Cubic Feet. | Feet of Head. | Cubic Feet. | Feet of Head. | Cubic Feet. | Feet of Head. | Cubic Feet. | Feet of Head. | Cubic Feet. | Feet of Head | Cubic Feet. | Feet of Head. | Cubic Feet. | Feet of Head | Cubic Feet. | Feet of Head. |
| 2 | 5·9 | ·97 | 10·5 | ·55 | 16·4 | ·41 | 23·6 | ·32 | 32 | ·27 | 42 | ·23 | 53 | ·19 | 65 | ·18 | 94 | ·15 | 128 | ·12 |
| 2·5 | 7·3 | 1·49 | 13 | ·12 | 20·4 | ·64 | 29·3 | ·50 | 40 | ·43 | 52 | ·36 | 66 | ·30 | 82 | ·27 | 117 | ·23 | 160 | ·19 |
| 3 | 8·8 | 1·9 | 15·7 | 1·2 | 24·5 | ·82 | 35·2 | ·72 | 48 | ·61 | 63 | ·51 | 79 | ·44 | 98 | ·39 | 141 | ·33 | 192 | ·27 |
| 3·5 | 10·3 | 2·6 | 18·3 | 1·6 | 28·6 | 1·2 | 41·2 | 1·0 | 56 | ·7 | 73 | ·71 | 93 | ·61 | 115 | ·52 | 165 | ·45 | 224 | ·37 |
| 4 | 11·8 | 3·3 | 21 | 2·2 | 32·7 | 1·7 | 47 | 1·3 | 64 | ·9 | 84 | ·92 | 106 | ·79 | 131 | ·69 | 188 | ·59 | 257 | ·49 |
| 4·5 | ... | ... | ... | ... | ... | ... | 53 | 1·6 | 72 | 1·2 | 94 | 1·2 | 119 | 1·01 | 147 | ·87 | 212 | ·75 | 288 | ·61 |
| 5 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 133 | 1·2 | 164 | 1·1 | 235 | ·90 | 320 | ·76 |
| 5·5 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 352 | ·92 |
| 6 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |

| | 15 | | 18 | | 21 | | 24 | | 27 | | 30 | | 33 | | 36 | | 42 | | 48 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Feet. | Cubic Feet. | Feet of Head. | Cubic Feet. | Feet of Head. | Cubic Feet. | Feet of Head. | Cubic Feet. | Feet of Head. | Cubic Feet. | Feet of Head. | Cubic Feet. | Feet of Head. | Cubic Feet. | Feet of Head. | Cubic Feet. | Feet of Head. | Cubic Feet. | Feet of Head. | Cubic Feet. | Feet of Head |
| 2 | 148 | ·11 | 212 | ·095 | 288 | ·075 | 377 | ·065 | 478 | ·055 | 590 | ·052 | 710 | ·049 | 850 | ·047 | 1150 | ·036 | 1500 | ·030 |
| 2·5 | 184 | ·17 | 264 | ·147 | 360 | ·117 | 470 | ·109 | 595 | ·088 | 730 | ·085 | 890 | ·076 | 1000 | ·067 | 1440 | ·056 | 1880 | ·046 |
| 3 | 220 | ·25 | 317 | ·21 | 430 | ·17 | 565 | ·15 | 715 | ·13 | 880 | ·12 | 1070 | ·108 | 1270 | ·10 | 1730 | ·081 | 2250 | ·067 |
| 3·5 | 258 | ·34 | 372 | ·29 | 505 | ·23 | 660 | ·20 | 835 | ·18 | 1030 | ·16 | 1250 | ·15 | 1480 | ·14 | 2020 | ·111 | 2630 | ·092 |
| 4 | 295 | ·44 | 425 | ·36 | 575 | ·31 | 755 | ·27 | 955 | ·23 | 1180 | ·22 | 1420 | ·20 | 1700 | ·17 | 2300 | ·14 | 3000 | ·116 |
| 4·5 | 331 | ·56 | 475 | ·46 | 650 | ·39 | 845 | ·34 | 1070 | ·30 | 1320 | ·28 | 1600 | ·25 | 1900 | ·22 | 2590 | ·18 | 3380 | ·15 |
| 5 | 368 | ·70 | 530 | ·58 | 720 | ·48 | 940 | ·41 | 1190 | ·37 | 1470 | ·34 | 1780 | ·30 | 2120 | ·27 | 2880 | ·22 | 3750 | ·18 |
| 5·5 | 405 | ·84 | 580 | ·70 | 790 | ·59 | 1030 | ·50 | 1310 | ·44 | 1610 | ·39 | 1950 | ·36 | 2330 | ·32 | 3170 | ·27 | 4130 | ·22 |
| 6 | ... | ... | ... | ... | ... | ... | 1130 | ·59 | 1430 | ·53 | 1760 | ·49 | 2140 | ·43 | 2540 | ·4 | 3450 | ·32 | 4500 | ·27 |

TABLE 329.—WATER DISCHARGED FROM NOZZLES ATTACHED TO 50 FEET OF 2½-INCH HOSE. (Freeman.)

| Hydrant Pressure. | 1⅜-Inch Smooth Nozzle. | | | 1¼-Inch Smooth Nozzle. | | | 1⅛-Inch Smooth Nozzle. | | | 1-Inch Smooth Nozzle. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Gals. per Min. | | | Gals. per Min. | | | Gals. per Min. | | | Gals. per Min. | | |
| Lbs. per Sq. Inch. | Unlined Linen Hose. | Inferior Rubber-lined Cotton "Mill Hose." Inside rough. | Ordinary best quality Rubber-lined Hose. Inside smooth. | Unlined Linen Hose. | Inferior Rubber-lined Cotton "Mill Hose." Inside rough. | Ordinary best quality Rubber-lined Hose. Inside smooth. | Unlined Linen Hose. | Inferior Rubber-lined Cotton "Mill Hose." Inside rough. | Ordinary best quality Rubber-lined Hose. Inside smooth. | Unlined Linen Hose. | Inferior Rubber-lined Cotton "Mill Hose." Inside rough. | Ordinary best quality Rubber-lined Hose. Inside smooth. |
| 5 | 75 | 78 | 86 | 67 | 68 | 75 | 58 | 59 | 63 | 49 | 49 | 52 |
| 10 | 106 | 109 | 122 | 95 | 97 | 106 | 83 | 84 | 89 | 69 | 70 | 73 |
| 15 | 129 | 133 | 149 | 117 | 119 | 129 | 101 | 103 | 109 | 84 | 85 | 88 |
| 20 | 150 | 154 | 172 | 134 | 137 | 149 | 117 | 118 | 126 | 98 | 98 | 103 |
| 25 | 168 | 173 | 192 | 150 | 153 | 167 | 130 | 132 | 141 | 109 | 110 | 114 |
| 30 | 183 | 188 | 209 | 164 | 168 | 183 | 143 | 144 | 153 | 119 | 120 | 125 |
| 35 | 198 | 204 | 227 | 178 | 182 | 197 | 153 | 157 | 166 | 128 | 130 | 135 |
| 40 | 212 | 218 | 243 | 189 | 194 | 211 | 164 | 168 | 178 | 138 | 139 | 144 |
| 45 | 225 | 232 | 258 | 201 | 206 | 224 | 174 | 178 | 188 | 146 | 147 | 153 |
| 50 | 237 | 244 | 271 | 213 | 217 | 236 | 184 | 187 | 198 | 153 | 155 | 162 |
| 55 | 248 | 256 | 284 | 223 | 228 | 247 | 193 | 196 | 209 | 161 | 163 | 170 |
| 60 | 259 | 267 | 298 | 233 | 238 | 258 | 202 | 204 | 218 | 168 | 170 | 178 |
| 65 | 270 | 278 | 309 | 242 | 247 | 268 | 210 | 213 | 227 | 175 | 178 | 184 |
| 70 | 280 | 297 | 321 | 251 | 256 | 278 | 218 | 221 | 234 | 182 | 184 | 192 |
| 75 | 290 | 299 | 333 | 259 | 265 | 285 | 225 | 229 | 243 | 188 | 190 | 198 |
| 80 | 299 | 308 | 344 | 268 | 278 | 298 | 233 | 237 | 251 | 194 | 197 | 205 |
| 85 | 309 | 318 | 354 | 277 | 283 | 308 | 240 | 244 | 258 | 200 | 203 | 211 |
| 90 | 318 | 328 | 364 | 283 | 291 | 316 | 247 | 251 | 266 | 206 | 208 | 218 |
| 95 | 327 | 335 | 374 | 292 | 298 | 325 | 253 | 258 | 273 | 211 | 214 | 223 |
| 100 | 335 | 345 | 383 | 299 | 307 | 333 | 260 | 264 | 281 | 217 | 220 | 229 |

| ⅞-In. Smooth Nozzle or 1-Inch Ring Nozzle. | | | ¾-In. Smooth Nozzle or ⅞-Inch Ring Nozzle. | | | 1⅜-Inch Ring Nozzle. | | | 1¼-Inch Ring Nozzle. | | | 1⅛-Inch Ring Nozzle. | | | Hydrant Pressure. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gals. per Min. | | | Gals. per Min. | | | Gals. per Min. | | | Gals. per Min. | | | Gals. per Min. | | | |
| Unlined Linen Hose. | Inferior Rubber-lined Cotton "Mill Hose." Inside rough. | Ordinary best quality Rubber-lined Hose. Inside smooth. | Unlined Linen Hose. | Inferior Rubber-lined Cotton "Mill Hose." Inside rough. | Ordinary best quality Rubber-lined Hose. Inside smooth. | Unlined Linen Hose. | Inferior Rubber-lined Cotton "Mill Hose." Inside rough. | Ordinary best quality Rubber-lined Hose. Inside smooth. | Unlined Linen Hose. | Inferior Rubber-lined Cotton "Mill Hose." Inside rough. | Ordinary best quality Rubber-lined Hose. Inside smooth. | Unlined Linen Hose. | Inferior Rubber-lined Cotton "Mill Hose." Inside rough. | Ordinary best quality Rubber-lined Hose. Inside smooth. | Lbs. per Sq. Inch. |
| 39 | 39 | 40 | 30 | 30 | 31 | 63 | 63 | 70 | 55 | 56 | 58 | 47 | 47 | 49 | 5 |
| 55 | 56 | 57 | 42 | 42 | 43 | 90 | 92 | 98 | 78 | 80 | 84 | 67 | 68 | 70 | 10 |
| 68 | 68 | 70 | 51 | 51 | 52 | 110 | 113 | 120 | 96 | 98 | 103 | 82 | 83 | 86 | 15 |
| 78 | 78 | 80 | 59 | 59 | 60 | 127 | 129 | 139 | 111 | 113 | 119 | 94 | 95 | 99 | 20 |
| 87 | 88 | 89 | 66 | 67 | 68 | 142 | 145 | 156 | 124 | 126 | 133 | 105 | 107 | 111 | 25 |
| 95 | 96 | 98 | 72 | 73 | 73 | 156 | 159 | 171 | 136 | 138 | 146 | 115 | 117 | 121 | 30 |
| 103 | 103 | 106 | 78 | 78 | 79 | 167 | 172 | 184 | 147 | 149 | 158 | 124 | 126 | 131 | 35 |
| 110 | 111 | 113 | 83 | 83 | 84 | 179 | 183 | 198 | 157 | 159 | 168 | 133 | 135 | 140 | 40 |
| 117 | 118 | 120 | 89 | 89 | 90 | 191 | 194 | 209 | 167 | 169 | 171 | 141 | 143 | 148 | 45 |
| 123 | 123 | 127 | 93 | 93 | 94 | 201 | 204 | 220 | 176 | 178 | 189 | 149 | 151 | 157 | 50 |
| 128 | 129 | 132 | 98 | 98 | 99 | 211 | 214 | 231 | 184 | 187 | 198 | 156 | 158 | 164 | 55 |
| 134 | 135 | 139 | 102 | 102 | 103 | 220 | 224 | 241 | 193 | 195 | 206 | 163 | 165 | 171 | 60 |
| 140 | 141 | 144 | 106 | 106 | 108 | 229 | 233 | 251 | 200 | 203 | 214 | 171 | 172 | 178 | 65 |
| 145 | 147 | 150 | 110 | 110 | 112 | 238 | 243 | 261 | 208 | 211 | 223 | 177 | 178 | 185 | 70 |
| 151 | 152 | 155 | 114 | 114 | 119 | 246 | 251 | 270 | 215 | 218 | 230 | 183 | 184 | 192 | 75 |
| 155 | 157 | 160 | 118 | 119 | 120 | 254 | 259 | 278 | 222 | 225 | 238 | 188 | 190 | 198 | 80 |
| 160 | 161 | 165 | 121 | 122 | 123 | 262 | 267 | 288 | 228 | 233 | 245 | 194 | 196 | 203 | 85 |
| 164 | 168 | 170 | 124 | 125 | 127 | 269 | 278 | 296 | 235 | 239 | 253 | 199 | 202 | 210 | 90 |
| 169 | 170 | 174 | 128 | 128 | 130 | 277 | 282 | 303 | 242 | 246 | 259 | 205 | 208 | 216 | 95 |
| 173 | 175 | 179 | 132 | 133 | 134 | 283 | 290 | 312 | 248 | 253 | 266 | 211 | 213 | 222 | 100 |

TABLE 330.—WATER DISCHARGED FROM NOZZLES ATTACHED TO 100 FEET OF 2½-INCH HOSE.

| Hydrant Pressure. | 1¾-Inch Smooth Nozzle. Gals. per Min. | | | 1½ Inch Smooth Nozzle. Gals. per Min. | | | 1¼-Inch Smooth Nozzle. Gals. per Min. | | | 1-Inch Smooth Nozzle. Gals. per Min. | | | ⅞-In. Smooth Nozzle or 1 Inch Ring Nozzle. Gals. per Min. | | | ¾-In. Smooth Nozzle or ⅞-Inch Ring Nozzle. Gals. per Min. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lbs. per Sq. Inch. | Unlined Linen Hose. | Inferior Rubber-lined Cotton "Mill Hose." Inside rough. | Ordinary best quality Rubber-lined Hose. Inside smooth. | Unlined Linen Hose. | Inferior Rubber-lined Cotton "Mill Hose." Inside rough. | Ordinary best quality Rubber-lined Hose. Inside smooth. | Unlined Linen Hose. | Inferior Rubber-lined Cotton "Mill Hose." Inside rough. | Ordinary best quality Rubber-lined Hose. Inside smooth. | Unlined Linen Hose. | Inferior Rubber-lined Cotton "Mill Hose." Inside rough. | Ordinary best quality Rubber-lined Hose. Inside smooth. | Unlined Linen Hose. | Inferior Rubber-lined Cotton "Mill Hose." Inside rough. | Ordinary best quality Rubber-lined Hose. Inside smooth. | Unlined Linen Hose. | Inferior Rubber-lined Cotton "Mill Hose." Inside rough. | Ordinary best quality Rubber-lined Hose. Inside smooth. |
| 5 | 63 | 66 | 78 | 58 | 60 | 68 | 52 | 53 | 59 | 45 | 46 | 49 | 37 | 38 | 39 | 28 | 28 | 29 |
| 10 | 89 | 93 | 101 | 82 | 85 | 97 | 73 | 76 | 83 | 63 | 65 | 69 | 53 | 53 | 55 | 40 | 41 | 42 |
| 15 | 101 | 105 | 133 | 101 | 104 | 119 | 90 | 93 | 103 | 78 | 79 | 85 | 63 | 64 | 68 | 49 | 50 | 51 |
| 20 | 126 | 131 | 154 | 116 | 120 | 137 | 104 | 107 | 118 | 89 | 92 | 98 | 73 | 74 | 78 | 57 | 58 | 59 |
| 25 | 141 | 147 | 173 | 129 | 134 | 153 | 116 | 119 | 132 | 100 | 102 | 110 | 83 | 83 | 88 | 63 | 64 | 65 |
| 30 | 154 | 160 | 188 | 142 | 147 | 168 | 127 | 130 | 144 | 110 | 112 | 120 | 90 | 92 | 96 | 70 | 70 | 73 |
| 35 | 167 | 173 | 204 | 153 | 158 | 182 | 138 | 141 | 157 | 119 | 121 | 130 | 98 | 99 | 103 | 75 | 76 | 78 |
| 40 | 178 | 185 | 218 | 164 | 170 | 194 | 147 | 151 | 168 | 127 | 128 | 139 | 104 | 106 | 111 | 81 | 81 | 83 |
| 45 | 188 | 197 | 232 | 174 | 180 | 206 | 156 | 160 | 178 | 134 | 138 | 148 | 110 | 112 | 118 | 86 | 86 | 88 |
| 50 | 199 | 208 | 244 | 183 | 190 | 217 | 164 | 168 | 187 | 142 | 145 | 155 | 116 | 118 | 123 | 90 | 91 | 93 |
| 55 | 209 | 218 | 256 | 193 | 199 | 228 | 173 | 177 | 196 | 148 | 152 | 163 | 122 | 123 | 129 | 94 | 95 | 98 |
| 60 | 218 | 228 | 267 | 201 | 208 | 238 | 180 | 185 | 204 | 155 | 158 | 170 | 128 | 129 | 135 | 98 | 99 | 102 |
| 65 | 227 | 237 | 278 | 209 | 217 | 247 | 188 | 193 | 213 | 162 | 165 | 178 | 133 | 134 | 141 | 103 | 103 | 106 |
| 70 | 235 | 245 | 288 | 218 | 225 | 256 | 194 | 200 | 221 | 168 | 171 | 184 | 138 | 139 | 147 | 107 | 108 | 110 |
| 75 | 243 | 253 | 298 | 225 | 233 | 266 | 201 | 207 | 229 | 173 | 176 | 190 | 143 | 144 | 152 | 110 | 111 | 114 |
| 80 | 251 | 262 | 308 | 232 | 240 | 274 | 208 | 213 | 237 | 179 | 183 | 197 | 148 | 149 | 157 | 114 | 115 | 118 |
| 85 | 259 | 270 | 318 | 239 | 248 | 283 | 214 | 220 | 244 | 185 | 188 | 203 | 152 | 154 | 161 | 118 | 119 | 122 |
| 90 | 267 | 278 | 328 | 246 | 255 | 291 | 220 | 227 | 251 | 190 | 194 | 208 | 157 | 158 | 166 | 121 | 122 | 125 |
| 95 | 274 | 285 | 336 | 253 | 262 | 298 | 227 | 233 | 258 | 195 | 199 | 214 | 160 | 163 | 170 | 124 | 125 | 128 |
| 100 | 281 | 293 | 345 | 259 | 268 | 307 | 233 | 239 | 264 | 200 | 204 | 220 | 164 | 167 | 175 | 128 | 128 | 132 |

| Hydrant Pressure. | 1⅜-Inch Ring Nozzle. Gals. per Min. | | | 1¼-Inch Ring Nozzle. Gals. per Min. | | | 1⅛-Inch Ring Nozzle. Gals. per Min. | | |
|---|---|---|---|---|---|---|---|---|---|
| Lbs. per Sq. Inch. | Unlined Linen Hose. | Inferior Rubber-lined Cotton "Mill Hose." Inside rough. | Ordinary best quality Rubber-lined Hose. Inside smooth. | Unlined Linen Hose. | Inferior Rubber-lined Cotton "Mill Hose." Inside rough. | Ordinary best quality Rubber-lined Hose. Inside smooth. | Unlined Linen Hose. | Inferior Rubber-lined Cotton "Mill Hose." Inside rough. | Ordinary best quality Rubber-lined Hose. Inside smooth. |
| 5 | 56 | 58 | 65 | 50 | 52 | 57 | 43 | 44 | 48 |
| 10 | 78 | 81 | 83 | 71 | 73 | 80 | 62 | 63 | 68 |
| 15 | 96 | 100 | 113 | 87 | 89 | 98 | 75 | 77 | 83 |
| 20 | 111 | 115 | 129 | 100 | 103 | 113 | 88 | 89 | 95 |
| 25 | 124 | 128 | 145 | 112 | 115 | 126 | 98 | 99 | 107 |
| 30 | 136 | 141 | 159 | 123 | 126 | 138 | 107 | 108 | 117 |
| 35 | 147 | 152 | 172 | 133 | 136 | 149 | 116 | 118 | 126 |
| 40 | 157 | 163 | 183 | 141 | 145 | 159 | 123 | 126 | 135 |
| 45 | 167 | 173 | 194 | 150 | 154 | 169 | 131 | 133 | 143 |
| 50 | 176 | 182 | 204 | 156 | 163 | 178 | 138 | 141 | 151 |
| 55 | 184 | 191 | 214 | 166 | 170 | 187 | 144 | 148 | 158 |
| 60 | 193 | 199 | 224 | 173 | 178 | 195 | 151 | 154 | 165 |
| 65 | 201 | 207 | 233 | 181 | 185 | 203 | 158 | 160 | 172 |
| 70 | 208 | 215 | 242 | 188 | 192 | 211 | 163 | 166 | 178 |
| 75 | 216 | 223 | 251 | 194 | 199 | 218 | 169 | 172 | 184 |
| 80 | 223 | 229 | 259 | 200 | 205 | 225 | 174 | 178 | 190 |
| 85 | 229 | 237 | 267 | 206 | 212 | 233 | 179 | 183 | 196 |
| 90 | 236 | 243 | 274 | 213 | 218 | 239 | 185 | 188 | 202 |
| 95 | 243 | 250 | 282 | 218 | 224 | 246 | 190 | 193 | 208 |
| 100 | 249 | 257 | 289 | 224 | 229 | 252 | 195 | 198 | 213 |

TABLE 331.—LOSS OF PRESSURE BY FRICTION PER 100 FEET OF 2½-INCH FIRE-HOSE, FOR GIVEN HEADS AND RATES OF DISCHARGE. (Fanning.)

| Head. | | Diameter of Nozzle in Inches. 1 Inch. Discharge per Minute. | Loss of Head by Friction. Rubber Hose. | Loss of Head by Friction. Leather Hose. | Distances reached by Jet. Horizontal. | Distances reached by Jet. Vertical. | 1⅛ Inches. Discharge per Minute. | Loss of Head by Friction. Rubber Hose. | Loss of Head by Friction. Leather Hose. | Distances reached by Jet. Horizontal. | Distances reached by Jet. Vertical. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Lbs. per Sq. In. | Feet. | Gallons. | Lbs. | Lbs. | Feet. | Feet. | Gallons. | Lbs. | Lbs. | Feet. | Feet. |
| 20 | 46·2 | 91·7 | 4·35 | 6·33 | 70 | 43 | 115·8 | 6·79 | 9·05 | 71 | 43 |
| 30 | 69·3 | 103·3 | 6·40 | 8·53 | 90 | 62 | 141·7 | 10·16 | 21·71 | 93 | 63 |
| 40 | 92·4 | 129·2 | 8·40 | 10·83 | 109 | 79 | 163·3 | 13·60 | 16·38 | 113 | 81 |
| 50 | 115·5 | 144·2 | 10·20 | 13·10 | 126 | 94 | 182·5 | 17·05 | 20·11 | 132 | 97 |
| 60 | 138·6 | 157·5 | 12·80 | 15·34 | 142 | 108 | 200·0 | 20·59 | 23·88 | 148 | 112 |
| 70 | 161·7 | 170·9 | 14·80 | 17·79 | 156 | 121 | 215·8 | 24·00 | 27·61 | 163 | 125 |
| 80 | 184·8 | 182·5 | 17·00 | 20·11 | 168 | 131 | 230·8 | 27·00 | 31·41 | 175 | 137 |
| 90 | 207·9 | 193·3 | 19·20 | 22·40 | 178 | 140 | 245·0 | 30·00 | 35·24 | 186 | 148 |
| 100 | 231·0 | 204·2 | 20·50 | 24·83 | 186 | 148 | 259·3 | 33·00 | 39·07 | 193 | 157 |
| | | 1¼ Inches. | | | | | 1⅜ Inches. | | | | |
| Lbs. per Sq. In. | Feet. | Gallons. | Lbs. | Lbs. | Feet. | Feet. | Gallons. | Lbs. | Lbs. | Feet. | Feet. |
| 20 | 46·2 | 142·5 | 10·28 | 12·84 | 73 | 43 | 172·5 | 15·00 | 18·81 | 75 | 44 |
| 30 | 69·3 | 175·0 | 15·64 | 19·00 | 96 | 63 | 210·8 | 22·96 | 26·39 | 100 | 65 |
| 40 | 92·4 | 201·7 | 20·85 | 24·07 | 118 | 82 | 244·2 | 29·40 | 35·01 | 124 | 85 |
| 50 | 115·5 | 225·8 | 25·46 | 30·11 | 138 | 99 | 273·3 | 40·50 | 43·38 | 146 | 102 |
| 60 | 138·6 | 247·5 | 29·50 | 35·94 | 156 | 115 | 290·8 | 48·20 | 52·00 | 166 | 118 |
| 70 | 161·7 | 266·7 | 39·00 | 41·57 | 172 | 129 | 322·5 | 55·70 | 60·40 | 184 | 133 |
| 80 | 184·8 | 285·0 | 43·81 | 47·36 | 186 | 142 | 344·2 | 64·70 | 68·59 | 200 | 146 |
| 90 | 207·9 | 302·5 | 49·42 | 53·25 | 198 | 154 | 374·2 | 72·00 | 70·73 | 213 | 158 |
| 100 | 231·0 | 319·2 | 55·00 | 59·20 | 207 | 164 | 385·0 | 79·26 | 84·87 | 224 | 169 |

TABLE 332.—DISCHARGE OF WATER OVER WEIRS IN STREAMS, FOR EACH INCH OF WIDTH.

| Depth on Weir. | Discharge per Minute per Inch Wide. | Depth on Weir. | Discharge per Minute per Inch Wide. | Depth on Weir. | Discharge per Minute per Inch Wide. | Depth on Weir. | Discharge per Minute per Inch Wide. |
|---|---|---|---|---|---|---|---|
| Inches. | Cub. Ft. | Inches. | Cub. Ft. | Inches. | Cub. Ft. | Inches. | Cub. Ft. |
| 1 | ·40 | 5½ | 5·18 | 10 | 12·71 | 14½ | 22·22 |
| 1⅛ | ·43 | 5⅝ | 5·36 | 10⅛ | 12·83 | 14⅝ | 22·51 |
| 1¼ | ·55 | 5¾ | 5·54 | 10¼ | 13·19 | 14¾ | 22·79 |
| 1⅜ | ·65 | 5⅞ | 5·72 | 10⅜ | 13·43 | 14⅞ | 23·08 |
| 1½ | ·74 | 6 | 5·90 | 10½ | 13·67 | 15 | 23·38 |
| 1⅝ | ·83 | 6⅛ | 6·00 | 10⅝ | 13·93 | 15⅛ | 23·53 |
| 1¾ | ·93 | 6¼ | 6·28 | 10¾ | 14·16 | 15¼ | 23·97 |
| 1⅞ | 1·03 | 6⅜ | 6·47 | 10⅞ | 14·42 | 15⅜ | 24·26 |
| 2 | 1·14 | 6½ | 6·65 | 11 | 14·67 | 15½ | 24·56 |
| 2⅛ | 1·19 | 6⅝ | 6·85 | 11⅛ | 14·79 | 15⅝ | 24·86 |
| 2¼ | 1·36 | 6¾ | 7·05 | 11¼ | 15·18 | 15¾ | 25·16 |
| 2⅜ | 1·47 | 6⅞ | 7·25 | 11⅜ | 15·43 | 15⅞ | 25·46 |
| 2½ | 1·59 | 7 | 7·44 | 11½ | 15·67 | 16 | 25·76 |
| 2⅝ | 1·71 | 7⅛ | 7·54 | 11⅝ | 15·96 | 16⅛ | 25·91 |
| 2¾ | 1·83 | 7¼ | 7·84 | 11¾ | 16·20 | 16¼ | 26·36 |
| 2⅞ | 1·96 | 7⅜ | 8·05 | 11⅞ | 16·46 | 16⅜ | 26·66 |
| 3 | 2·09 | 7½ | 8·25 | 12 | 16·73 | 16½ | 26·97 |
| 3⅛ | 2·16 | 7⅝ | 8·45 | 12⅛ | 16·86 | 16⅝ | 27·27 |
| 3¼ | 2·36 | 7¾ | 8·66 | 12¼ | 17·26 | 16¾ | 27·58 |
| 3⅜ | 2·50 | 7⅞ | 8·86 | 12⅜ | 17·52 | 16⅞ | 27·89 |
| 3½ | 2·63 | 8 | 9·10 | 12½ | 17·78 | 17 | 28·20 |
| 3⅝ | 2·78 | 8⅛ | 9·20 | 12⅝ | 18·05 | 17⅛ | 28·35 |
| 3¾ | 2·92 | 8¼ | 9·52 | 12¾ | 18·32 | 17¼ | 28·82 |
| 3⅞ | 3·07 | 8⅜ | 9·74 | 12⅞ | 18·58 | 17⅜ | 29·14 |
| 4 | 3·22 | 8½ | 9·96 | 13 | 18·87 | 17½ | 29·45 |
| 4⅛ | 3·29 | 8⅝ | 10·18 | 13⅛ | 19·01 | 17⅝ | 29·76 |
| 4¼ | 3·52 | 8¾ | 10·40 | 13¼ | 19·42 | 17¾ | 30·08 |
| 4⅜ | 3·68 | 8⅞ | 10·62 | 13⅜ | 19·69 | 17⅞ | 30·39 |
| 4½ | 3·83 | 9 | 10·86 | 13½ | 19·97 | 18 | 30·70 |
| 4⅝ | 3·99 | 9⅛ | 10·97 | 13⅝ | 20·24 | 18⅛ | 30·86 |
| 4¾ | 4·16 | 9¼ | 11·31 | 13¾ | 20·52 | 18¼ | 31·34 |
| 4⅞ | 4·32 | 9⅜ | 11·54 | 13⅞ | 20·80 | 18⅜ | 31·66 |
| 5 | 4·50 | 9½ | 11·77 | 14 | 21·09 | 18½ | 31·98 |
| 5⅛ | 4·58 | 9⅝ | 12·00 | 14⅛ | 21·23 | 18⅝ | 32·31 |
| 5¼ | 4·84 | 9¾ | 12·23 | 14¼ | 21·65 | 18¾ | 32·63 |
| 5⅜ | 5·01 | 9⅞ | 12·47 | 14⅜ | 21·94 | 18⅞ | 32·96 |

### Measurement of Water in a Stream.

To measure the volume of water flowing past a given point in a stream per minute, select a portion of the stream, uniform or nearly uniform in width, throw into the middle of the stream, a floating body sufficiently heavy to be almost totally immersed, as a bottle partly filled with water, and note the time taken to float from one mark to another; or, note the distance traversed by the float in one minute. The observation should be repeated several times to give an average result. Measure several sections of the stream within the measured distance, and multiply the average area in square feet by the distance in feet. From the volume thus calculated, one-fifth is deducted, as an allowance for retardation by frictional resistance at the bottom and sides, to give the volume of flow in cubic feet per minute.

Another method of measurement, admitting of more nearly exact results, is to cause the water to flow over a weir, by fixing a board across the stream where it flows slowly, having a notch cut into it broad enough and deep enough for all the water to pass over and fall freely. At the distance of a yard or two from the notch, up-stream, fix a rod, and mark on it the level of the crest of the notch, measure the height of the water surface above this mark, to give the depth of the crest below the surface of the water. Find in the Table 332, calculated according to Du Buat's formula, the observed depth in inches, and multiply it by the corresponding value in the next column, which expresses the volume discharged for each inch in width of the crest. The product is the whole volume of water discharged in cubic feet per minute.

For example, if the depth over a weir 50 inches wide be 6½ inches, find 6½ inches in the columns of depths, and note in the next column the quantity of water, 6·65 cubic feet per inch wide per minute. Multiply 6·65 by 50; the product is 332·5 cubic feet, the volume discharged per minute.

### Discharge of Water from a Tank over a Tumbling Bay.

Messrs. B. Donkin & Co. have made observations of the quantity of water discharged from a tank, over a rectangular notch, tumbling bay or weir, cut into a brass or copper sheet, ⅛ inch thick, fastened to the inside of the tank. The bay was 6 inches wide. The levels of water were observed on the same system as already described for the measurement of streams.

The width of the bay should not in any case be greater than one-third of the width of the tank. Table 333 gives the weight and volume of water falling over a bay 6 inches wide, in one minute, for depths of from 1¼ in. to $4\frac{15}{16}$ ins. over the bay.

For bays of greater width than 6 inches, the rate of discharge is increased in the same proportion.

TABLE 333.—QUANTITY OF WATER DISCHARGED OVER A TUMBLING BAY, 6 INCHES WIDE. (Donkin.)

| Depth over Tumbling Bay. | Water per Minute. | | Depth over Tumbling Bay. | Water per Minute. | |
|---|---|---|---|---|---|
| Inches. | Pounds. | Cub. Ft. | Inches. | Pounds. | Cub. Ft. |
| $1\frac{1}{2}$ | 274 | 4·39 | $3\frac{1}{4}$ | 874 | 14·00 |
| $1\frac{9}{16}$ | 292 | 4·67 | $3\frac{5}{16}$ | 900 | 14·43 |
| $1\frac{5}{8}$ | 310 | 4·96 | $3\frac{3}{8}$ | 926 | 14·83 |
| $1\frac{11}{16}$ | 327 | 5·24 | $3\frac{7}{16}$ | 951 | 15·24 |
| $1\frac{3}{4}$ | 345 | 5·52 | $3\frac{1}{2}$ | 977 | 15·65 |
| $1\frac{13}{16}$ | 365 | 5·84 | $3\frac{9}{16}$ | 1003 | 16·08 |
| $1\frac{7}{8}$ | 383 | 6·13 | $3\frac{5}{8}$ | 1030 | 16·44 |
| $1\frac{15}{16}$ | 402 | 6·44 | $3\frac{11}{16}$ | 1056 | 16·84 |
| 2 | 421 | 6·74 | $3\frac{3}{4}$ | 1083 | 17·35 |
| $2\frac{1}{16}$ | 442 | 7·08 | $3\frac{13}{16}$ | 1112 | 17·82 |
| $2\frac{1}{8}$ | 462 | 7·40 | $3\frac{7}{8}$ | 1139 | 18·25 |
| $2\frac{3}{16}$ | 483 | 7·74 | $3\frac{15}{16}$ | 1166 | 18·68 |
| $2\frac{1}{4}$ | 503 | 8·06 | 4 | 1193 | 19·11 |
| $2\frac{5}{16}$ | 525 | 8·41 | $4\frac{1}{16}$ | 1221 | 19·56 |
| $2\frac{3}{8}$ | 547 | 8·76 | $4\frac{1}{8}$ | 1250 | 20·01 |
| $2\frac{7}{16}$ | 568 | 9·10 | $4\frac{3}{16}$ | 1279 | 20·49 |
| $2\frac{1}{2}$ | 589 | 9·43 | $4\frac{1}{4}$ | 1306 | 20·93 |
| $2\frac{9}{16}$ | 612 | 9·80 | $4\frac{5}{16}$ | 1336 | 21·41 |
| $2\frac{5}{8}$ | 634 | 10·16 | $4\frac{3}{8}$ | 1365 | 21·87 |
| $2\frac{11}{16}$ | 657 | 10·36 | $4\frac{7}{16}$ | 1394 | 22·34 |
| $2\frac{3}{4}$ | 680 | 10·89 | $4\frac{1}{2}$ | 1424 | 22·82 |
| $2\frac{13}{16}$ | 704 | 11·28 | $4\frac{9}{16}$ | 1454 | 23·30 |
| $2\frac{7}{8}$ | 727 | 11·65 | $4\frac{5}{8}$ | 1483 | 23·76 |
| $2\frac{15}{16}$ | 751 | 12·05 | $4\frac{11}{16}$ | 1514 | 24·26 |
| 3 | 775 | 12·41 | $4\frac{3}{4}$ | 1544 | 24·74 |
| $3\frac{1}{16}$ | 800 | 12·82 | $4\frac{13}{16}$ | 1575 | 25·24 |
| $3\frac{1}{8}$ | 825 | 13·22 | $4\frac{7}{8}$ | 1605 | 25·72 |
| $3\frac{3}{16}$ | 850 | 13·62 | $4\frac{15}{16}$ | 1635 | 26·22 |

Messrs. Donkin and Salter made more recent measurements of the flow of water over a bay of rectangular form, $1\frac{1}{2}$ inches wide cut square out of sheet brass $\frac{1}{16}$ inch thick. They give the general formula for theoretical discharge, reduced for pounds and inches, as follows:—

$$Q = L\ 40{\cdot}032\sqrt{h^3} \quad . \quad . \quad . \quad . \quad (4)$$

$L$ = length of bay, in inches. $h$ = head, or height over bar in inches. $Q$ = pounds of water discharged, per minute.

The co-efficients of actual discharge vary from 64 to 62 per cent. of the theoretical discharge, for heads of from ½ inch to 3 inches.

### Flow of Water through a Submerged Weir.

A horizontal rectangular opening, 6 inches deep, 6 feet wide, was made in a board 5 inches thick, the upper and lower surfaces being rounded to a semicircular section, 2½ inches radius. The opening was entirely submerged at the inner side, under heads of from 6 inches to 4 feet. The efficiency of discharge varied from 73 per cent. to 78 per cent.

### Water Power.

The power of a fall of water for work, is measured by the product of the weight of water falling in a given time, by the height of the fall. The fall is measured from the surface of the head-water to the surface of the tail-water when the mill is at work. In calculations of water power, the weight of a cubic foot of water is commonly taken at 62½ pounds.

The potential horse-power of a stream is measured in the same way in terms of the fall or difference of level of the upper and lower gauge points.

The proportion of the horse-power of the fall that can be utilised depends upon the efficiency of the motor.

### Water-Wheels.

Under-shot wheels, having radial floats, are from 10 feet to 25 feet in diameter, and have an efficiency of from 27 per cent. to 30 per cent. Poncelet's under-shot wheels have curved floats. The efficiency is about 65 per cent. for falls of 4 feet or less; and from 55 per cent. to 50 per cent. for falls of from 6 feet to 6½ feet. The velocity of the floats should be 55 per cent. of that of the water.

Breast wheels have an efficiency of 70 per cent. when the height of the fall is about 8 feet; 50 per cent. for 4 feet of fall. The most suitable velocity of the floats is 4¼ feet per second. The diameter should be at least 11½ feet; it is seldom more than double this.

Over-shot wheels are employed for heads of from 13 feet to 20 feet. The velocity of the floats should be at least 3 feet per second: say 6½ feet for the smaller diameters; 10 feet for the larger diameters. The efficiency is from 70 to 75 per cent.

Whitelaw's water-mill—a development of Barker's mill—has been proved experimentally to show 76 per cent. of efficiency. In ordinary, the efficiency is about 55 per cent.

The Fourneyson turbine, having an outward flow, has an efficiency of from 60 per cent. to 70 per cent. The Jonval turbine, having a downward flow, has usually 72 per cent.

efficiency, under a full charge. It varies from 68 per cent. to 80 per cent. The vortex wheel, or inward-flow turbine, designed by Mr. James Thomson, has realised an efficiency of 77½ per cent. The Swain turbine, in which an inward and a downward discharge are combined, when tested by Mr. J. B. Francis, realised a maximum efficiency of 84 per cent. At half gate the maximum efficiency was 78 per cent.

The Girard turbine, or tangential wheel, has yielded an efficiency of 87 per cent.; at moderate speeds, in ordinary practice, from 75 per cent. to 80 per cent.

## Hydraulic Power.

The Armstrong hydraulic machines work with efficiency varying with the multiplying gear, as follows:—

| | Efficiency per cent. | | Efficiency per cent. | | Efficiency per cent. |
|---|---|---|---|---|---|
| Direct-acting | 93 | 6 to 1 | 72 | 12 to 1 | 59 |
| 2 to 1 | 89 | 8 to 1 | 67 | 14 to 1 | 54 |
| 4 to 1 | 76 | 10 to 1 | 63 | 16 to 1 | 50 |

Conditions:—Ordinary pump packing, with sheaves and wrought-iron pins. With special precautions, comprising large sheaves, and small hard pins, the efficiency of a machine multiplying 20 to 1 was as high as 66 per cent. With the accumulator rising or falling, at 700 lbs. pressure per square inch, the friction of the ram is about 2¼ per cent.

The loss by friction in a steam-engine pumping into an accumulator, has been taken at 8·3 per cent. The ultimate efficiency is given by compounding the engine efficiency with the efficiency of the machine.

The ram of the hydraulic press is packed with a leather collar, the friction of which is 1 per cent. of the pressure for a 4-in. ram; ½ per cent. for 8-in. ram; ¼ per cent. for 16-in ram.

## Hydraulic Transmission of Motive Power.

At the Central Pumping Station, Falcon Wharf, Blackfriars, of the London Hydraulic Power Company, there are two accumulators having 20-inch rams of 23-feet stroke, loaded for a pressure of 750 lbs. per square inch. At the Philip Lane Pumping Station, the accumulator is 13 feet above those, and is loaded to 710 lbs. per square inch. The delivery of power-water from Falcon Wharf is through four 6-inch mains; and, at 200 yards distance, through five 6-inch mains. The delivery is 1040 gallons per minute, at a velocity averaging 2·83 feet per second, or 170 feet per minute. The loss of head due to this velocity is 22·896 feet per 1000 yards, by the formula:—

$$\frac{(\text{Gallons per minute})^2 \times \text{length of pipe in yards}}{(3 \times \text{diameter of pipe in inches})}$$

The most distant point of the main is 5320 yards, or just over 3 miles, from the accumulators. In a circuit of 5 miles, the normal difference of pressure, or loss of head, was 20 feet head. To allow for such losses, as well as for valve passages and bends, the stated pressure supplied is 700 lbs. per square inch. At the end of 1887, the total length of mains laid was nearly 27 miles. There were then about 600 machines working from the mains in London, when the largest quantity of power delivered in one week was a little over 2,000,000 gallons, or 3,333 gallons per machine. The maximum consumption in any one hour was 35,000 gallons; the minimum, 1500 gallons. The practical efficiency—brake horse-power of hydraulic motors—may be fixed, says Mr. E. B. Ellington, the engineer of the company, at from 50 to 60 per cent. of the indicator power developed at the central station.

By the results of special trials, when 178½ indicator horse-power was developed, 4558 gallons of water were pumped per cwt. of coal consumed, with the Vicars stoker; 2·19 pounds of rough small coal being consumed per indicator horse-power per hour. In a trial for one week, under ordinary conditions, 3399 gallons of water were pumped per cwt. of coal consumed.

### Hydraulic Machine Tools (Tweddell's System).

Hydraulic pressure is used with great economy instead of the heavy gearing otherwise required to obtain the enormous power now used for riveting, punching, shearing and forging machines.

It is the cheapest and most efficient mode of transmitting power from the prime mover, especially in cases where the machines are spread over a large area of ground.

The efficiency of the pumps themselves is about 96, and that of the accumulator 99 per cent., and as the working parts of each tool practically only consist of a direct-acting ram, the loss by friction in the machine is equally small, and is at a minimum when doing useful work.

The pressure used by Mr. Tweddell (and almost invariably adopted as the standard one) is 1,500 lbs. per square inch. At this pressure, a pipe of ½-inch bore, at a speed of 5 feet per second, transmits 2·67 actual horse-power, a 1-inch pipe 10·7 horse-power, and a 1½-inch pipe 24, without any appreciable loss of efficiency.

The Tweddell Stationary Riveting Machines frequently put a pressure of 150 tons on rivet heads, closing them at the rate of from 3 to 5 per minute; but they are also made to exert pressures of 5 to 10 tons only for small rivets. Tweddell's Portable Riveters are used in all large bridge contracts for

TABLE 334.—SPEEDS OF CUTTING TOOLS. (J. Rose.)

| Work Diameter. Inches. | Roughing Cuts. Feet per Minute. | Roughing Cuts. Lathe Revolutions per Minute. | Feed or Lathe Revolutions per Inch of Tool Travel. | Finishing Cuts. Lathe Revolutions per Minute. | Finishing Cuts. Lathe Revolutions per Inch Tool Travel. |
|---|---|---|---|---|---|
| | | WROUGHT IRON. | | | |
| ½ | 40 | 305 | 30 | 305 | 60 |
| 1 | 35 | 133 | 30 | 133 | 60 |
| 1½ | 30 | 76 | 30 | 76 | 60 |
| 2 | 28 | 53 | 25 | 53 | 69 |
| 2½ | 28 | 42 | 25 | 42 | 50 |
| 3 | 28 | 35 | 25 | 35 | 50 |
| 3½ | 26 | 28 | 25 | 30 | 50 |
| 4 | 26 | 24 | 20 | 26 | 50 |
| 5 | 25 | 18 | 20 | 21 | 50 |
| 6 | 25 | 15 | 20 | 16 | 50 |
| | | CAST IRON. | | | |
| 1 | 45 | 163 | 30 | 163 | 40 |
| 1½ | 45 | 135 | 25 | 135 | 30 |
| 2 | 40 | 76 | 25 | 76 | 25 |
| 2½ | 40 | 61 | 20 | 61 | 20 |
| 3 | 35 | 44 | 20 | 50 | 16 |
| 3½ | 35 | 38 | 18 | 43 | 16 |
| 4 | 35 | 33 | 18 | 38 | 16 |
| 4½ | 30 | 25 | 16 | 28 | 14 |
| 5 | 30 | 22 | 16 | 26 | 14 |
| 5½ | 30 | 20 | 14 | 24 | 12 |
| 6 | 30 | 19 | 14 | 22 | 12 |
| | | BRASS. | | | |
| ½ | 120 | 910 | 25 | 910 | 40 |
| ¾ | 110 | 556 | 25 | 556 | 40 |
| 1 | 100 | 382 | 25 | 382 | 40 |
| 1¼ | 90 | 275 | 25 | 275 | 40 |
| 1½ | 80 | 203 | 25 | 203 | 40 |
| 1¾ | 80 | 174 | 25 | 174 | 40 |
| 2 | 75 | 143 | 25 | 143 | 40 |
| 2½ | 75 | 114 | 25 | 114 | 40 |
| 3 | 70 | 89 | 25 | 89 | 40 |
| 3½ | 70 | 76 | 25 | 76 | 40 |
| 4 | 70 | 66 | 25 | 66 | 40 |
| 4½ | 65 | 55 | 25 | 55 | 40 |
| 5 | 65 | 50 | 25 | 50 | 40 |
| 5½ | 65 | 45 | 25 | 45 | 40 |
| 6 | 65 | 41 | 25 | 41 | 40 |
| | | TOOL STEEL. | | | |
| ⅜ | 24 | 245 | 60 | 245 | 60 |
| ½ | 24 | 184 | 60 | 184 | 60 |
| ⅝ | 24 | 147 | 50 | 147 | 60 |
| ¾ | 24 | 122 | 40 | 122 | 60 |
| ⅞ | 20 | 87 | 30 | 87 | 60 |
| 1 | 20 | 76 | 30 | 76 | 60 |
| 1¼ | 20 | 61 | 25 | 61 | 50 |
| 1½ | 18 | 45 | 25 | 45 | 50 |
| 2 | 18 | 34 | 25 | 34 | 50 |
| 2½ | 18 | 27 | 25 | 27 | 50 |
| 3 | 18 | 22 | 25 | 22 | 40 |
| 3½ | 18 | 19 | 25 | 19 | 40 |
| 4 | 18 | 17 | 25 | 17 | |
| 4½ | 18 | 15 | 25 | 15 | |

riveting up the bridges *in situ*, as was first done by Mr. Tweddell on the Primrose Street bridge, London, in 1873.

As many as 5,000 ⅞-inch rivets have been put in per day of 9¼ hours by Messrs. Sellers at their Edgemore Works in the U.S.A. by these machines, and for a time they put in from 17 to 20 rivets per minute.

Many of the Flanging Presses exert 650 tons of pressure. This system is also largely employed for cranes, placed over the machine tools, whether hydraulic or geared.

At the present time about 2,000 of these hydraulic machine tools of various types are at work.

### Speed of Cutting Tools.

For cast-iron, 150 to 190 inches per minute; boring, 80 inches per minute.

For wrought-iron, 260 to 280 inches per minute.

For yellow brass, 300 inches per minute.

### Wood-Working Machinery.

| | Feet per Minute. |
|---|---|
| Teeth of circular saws | 9,000 |
| Cutter blocks for planing and moulding (cutting edge) | 6,000 |
| Irregular moulding and shaping machines (ditto) | 5,000 |
| Band-saw for cutting metals | 250 |
| Band-saw blades | 4,000 |
| Saw and cutter sharpening machine | 5,000 |
| Shafting | 250 revolutions. |

## COLOURS.

TABLE 335.—COLOURS USED IN MECHANICAL AND ARCHITECTURAL DRAWING, TO REPRESENT VARIOUS MATERIALS.

| Materials. | Colours used. |
|---|---|
| Brass | Gamboge. |
| Brickwork (in section) | Crimson lake. |
| Brickwork (in elevation) | Crimson lake, mixed with burnt sienna. |
| Cement | Sepia. |
| Concrete | Sepia, mottled, with burnt umber. |
| Copper | Crimson lake, mixed with gamboge. |
| Glass | Cobalt (blue), mottled. |
| Iron (wrought) | Prussian blue. |
| Iron (cast) | Payne's grey. |
| Lead | Indigo, or light Indian ink. |
| Leather | Vandyke brown. |
| Plaster | Sepia. |
| Slate | Indigo, mixed with crimson lake. |
| S[illegible] | Crimson lake, mixed with Prussian blue. |
| [illegible] | Burnt umber. |
| [illegible] | Indian red. |
| [illegible] | Burnt sienna |

# ELECTRICAL ENGINEERING.

## Electrical Units.

| Unit. | Name. | Derivation. | Dimensions in C. G. S.* Units. |
|---|---|---|---|
| Electromotive Force . . | Volt . . | Ampère × Ohm . | $10^8$ |
| Resistance . . | Ohm . . . | Volt ÷ Ampère . | $10^9$ |
| " . . | Megohm . | 1 million Ohms | $10^{15}$ |
| Current . . | Ampère . . | Volt ÷ Ohm . | $10^{-1}$ |
| " . . | Milliampère | 1 thousandth Ampère . . | $10^{-4}$ |
| Quantity . . | Coulomb . . | Ampère × Second | $10^{-1}$ |
| Capacity . . | Farad . . | Coulomb ÷ Volt | $10^{-9}$ |
| " . . | Microfarad . | 1 millionth Farad . . | $10^{-15}$ |

* C. G. S. = Centimètre-Gramme-Second.

For electric light and power purposes the Ampère is the practical unit of current.

For telegraph purposes the Milliampère is the practical unit of current.

The B.A. (British Association) Ohm, the unit of resistance in general use = resistance of column of pure mercury 1·0482 mètres long, 1 sq. mm. section at 0° C.; it is less in value than the true Ohm, which according to most recent determinations is $\frac{1·0627}{1·0482}$ of the B.A. Ohm.

The Siemens Mercury Unit = ·9540 B.A. Unit.

Insulation resistances are usually measured in Megohms (1,000,000 ohms).

When a current of 1 Ampère flows, electricity is passing at the rate of 1 Coulomb per second.

A capacity of 1 Farad charged to a potential of 1 Volt contains 1 Coulomb of electricity.

The Microfarad is the practical unit of capacity; it is the capacity of about $\frac{1}{3}$rd of a mile of submarine cable.

A Daniell Cell has roughly an Electromotive Force of 1·07 Volts.

### Electro-Mechanical Units.

Rate at which work is being done or energy expended in a resistance, R, through which a current, C, is flowing, there being an electromotive force or potential difference, E, between the ends of the resistance is

$$EC,\ C^2 R,\ \text{or}\ \frac{E^2}{R},\ \text{Watts.}$$

1 Watt = $\frac{1}{746}$th of a horse-power, *i.e.*, 1 horse-power = 746 Watts.

1 Kilowatt = 1000 Watts = 1·34 horse-power.

1 Watt = 1 Joule per sec.

A current of 1 Ampère flowing through a resistance of 1 Ohm for 1 sec. does 1 Joule of work.

1 Joule will raise ·238 grammes of water 1° C. in temperature.

1 Calorie is the amount of heat required to raise 1 gramme of water 1° C.

1 Joule = ·238 calories.

1 Joule = ·7373 foot-lbs. = 10,000,000 Ergs.

1 Erg (the absolute unit of *work*) = 1 Centimètre-dyne.

1 Dyne (the absolute unit of *force*) is that force which, acting for 1 sec. on a weight of 1 gramme on a smooth horizontal plane, will give it a velocity of 1 centimètre per sec.

Board of Trade unit = 1000 Watt-hours = work done by 1·34 horse-power during 1 hour.

### Measurement of Resistances.

For general purposes, the measurement of resistances is most conveniently effected by the Post Office pattern of Wheatstone bridge, the plan of connections of which is shown in Fig. 81.

## Wheatstone Bridge.

*Post Office Pattern.*

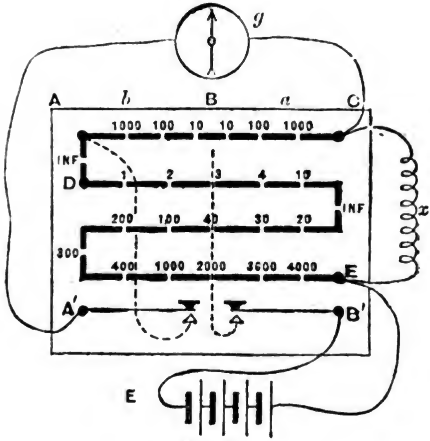



FIG. 81.

$x$ is the resistance to be measured, $g$ a galvanometer of about 1000 ohms resistance, and E a battery (which for ordinary purposes may be about 10 Leclanché cells). In making a measurement plugs must be removed from $a$ and $b$, and the right hand key pressed and kept down, then the left hand key must be alternately depressed and raised, plugs being removed from between D and E until no movement of the galvanometer needle is observed to take place on the depression and raising of the key. When balance is thus obtained

$$x = \frac{a}{b}\, r$$

$r$ being the resistance unplugged between D and E (the greatest value of this resistance is 10,000 ohms). By making $a$ greater than $b$ resistances greater than the whole of the resistance between D and E, *i.e.*, 10,000 ohms, can be measured, the greatest value being 1,000,000 ohms, which is obtained by making $a = 1000$ and $b = 10$, for when $r = 10{,}000$ ohms, then

$$x = \frac{1000}{10} \times 10{,}000 = 1{,}000{,}000 \text{ ohms.}$$

By making $a$ less than $b$ resistances less than 1 ohm can be measured, the least value being ·01 ohm, which is obtained by making $a = 10$ and $b = 1000$, for when $r = 1$ ohm, then

$$x = \frac{10}{1000} \times 1 = \cdot 01 \text{ ohms.}$$

**Individual Resistance of Three or more Telegraph Wires.**

In order to avoid errors due to earth currents or an imperfect earth when measuring the conductor resistance of 3 or more telegraph wires,

Loop wires 1 and 2 and let measured resistance be $r_1$
,, ,, 1 ,, 3 ,, ,, ,, $r_2$
,, ,, 2 ,, 3 ,, ,, ,, $r_3$

then

$$\text{Resistance of No. 1 Wire} = \frac{r_1 + r_2 - r_3}{2}$$

,, ,, 2 ,, $= r_1 -$ Resistance of No. 1 Wire
,, ,, 3 ,, $= r_3 -$ ,, ,, 2 ,,

As the resistance of No. 1 wire is thus known we can loop it with any number of other wires, and having ascertained the resistances of the loops, the resistance of any one of the wires is given by subtracting the resistance of No. 1 wire from the resistance of the loop.

**Measurement of Low Resistances.**

For measuring low resistances—*i.e.* resistances of less than 1 ohm—with accuracy, the measurements are usually made by means of the " Metre " bridge :—

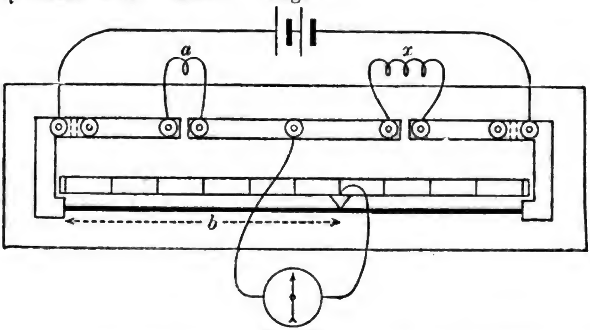



FIG. 82.

$a$ is a standard resistance of 1 ohm, $x$ is the low resistance to be measured. A slider connected to one end of the galvanometer is moved until no movement of the needle takes place on depressing the slider contact, then

$$x = \frac{1000}{b} - 1$$

The galvanometer should have a resistance of about $\frac{1}{10}$th ohm, and the battery should be about 2 large size Leclanché cells. Great care should be taken that all the connections to the terminals are well made, and that the surfaces in contact are scraped bright.

### Measurement of High Resistances.

For measuring high resistances, *i.e.* resistances exceeding 1 megohm, such as the *Insulation resistance* of a well insulated wire, the bridge method cannot be adopted with accuracy; in these cases the "deflection" method must be used, and a galvanometer of high resistance and one in which the deflections are directly proportional to the current, be employed. The galvanometer most suitable for the purpose is the "Thomson Reflecting."

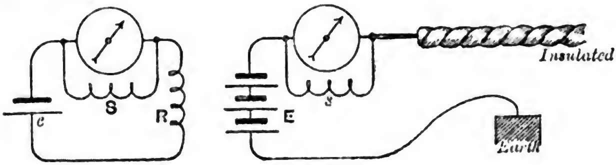



FIG. 83.

A small battery $e$ (usually 1 cell) is first connected up with the galvanometer and with a resistance R of 10,000 ohms (the resistance between D and E of the Post Office Wheatstone bridge may be used for the purpose), the galvanometer being shunted by a shunt S (usually the $\frac{1}{1000}$th shunt) so that a convenient deflection D is obtained; this is called taking the *constant*. The connections are then altered as shown by the second fig., a large battery E (about 100 or more cells) being used, and the wire whose insulation is to be measured being joined up as shown. Let the deflection be $d$, and the shunt, $s$, on the galvanometer be the $\frac{1}{n}$th (usually $\frac{1}{10}$th, $\frac{1}{100}$th or $\frac{1}{1000}$th, *i.e.* $n = 10$, 100, or 1000); also let the shunt used when the *constant* is taken be the $\frac{1}{N}$th shunt, then

$$\text{Insulation resistance of wire} = \frac{D \times N}{n} \times K \div d$$

where K is the ratio between the number of cells used in taking D and in taking the constant; thus if $d$ is given by 100 cells and D by 1 cell, then $K = 100$. When great accuracy is required, the exact ratio of the force of the large to the small battery has to be determined, for it is seldom that 100 cells have exactly 100 times the force of 1 cell, though in a large number of cases it is sufficient to consider it as such, care being taken that the cells are all in good condition. If a *megohm* resistance (1,000,000 ohms) is available, the *constant* may be taken with the same battery as is used for testing the insulated wire, the megohm being used in the place of the 10,000 ohms: in this case $K = 1$.

Care should be taken that the ends of the insulated wire being tested are well trimmed and quite dry; preferably the ends should be painted over with, or dipped for a moment in, hot paraffin *wax*, *not* paraffin *oil*.

### Combined Resistances.

The joint resistance of any number of resistances joined in parallel or multiple arc, is equal to the reciprocal of the sum of the reciprocals of their respective resistances; thus the joint resistance in parallel of wires whose resistances are $r_1$, $r_2$, $r_3$, $r_4$, &c., is

$$\frac{1}{\frac{1}{r_1}+\frac{1}{r_2}+\frac{1}{r_3}+\frac{1}{r_4}+\ldots}$$

If there are only *two* resistances, then their joint resistance in parallel is equal to the product of their values divided by their sum, or

$$\frac{r_1 r_2}{r_1+r_2}$$

### Shunts.

If C = total current flowing through a galvanometer of resistance G shunted by a resistance S, and $c$ the portion of this current flowing through the galvanometer, then

$$C = c\,\frac{G+S}{S}.$$

$\frac{G+S}{S}$ is called the *multiplying power* of the shunt.

The joint resistance of the galvanometer and shunt is

$$\frac{GS}{G+S}.$$

The shunt required to give a certain multiplying power $n$ is

$$\frac{G}{n-1}.$$

The joint resistance of the shunt and galvanometer in this case is

$$\frac{G}{n}.$$

If it is required to make up for the reduction of resistance in the circuit caused by the addition of the shunt, a *compensating* resistance,

$$\frac{G^2}{G+S}, \text{ or } G\,\frac{n-1}{n}.$$

must be added in the circuit.

**Ratio of Current to Resistance and Potential Difference.**

C = current flowing through a wire,
V = potential difference between its ends,
R = resistance of wire,

$$C = \frac{V}{R}, \quad R = \frac{V}{C}, \quad V = C\,R.$$

**Corrections for Temperature.**

For general Telegraphic and Electric Light purposes, the resistances of copper conductors are reduced or corrected from the measured results at the observed temperature to the values at 60° F., this being the normal temperature of the air; this reduction can be effected by the following Table :—

TABLE 336.—MULTIPLYING COEFFICIENTS FOR REDUCING THE OBSERVED RESISTANCE OF ORDINARY COPPER WIRE AT ANY TEMPERATURE TO 60° F.

| Temp. F. | Coeff. | Temp. ° F. | Coeff. | Temp. ° F. | Coeff. | Temp. ° F. | Coeff. | Temp. ° F. | Coeff. |
|---|---|---|---|---|---|---|---|---|---|
| 90 | ·9392 | 79 | ·9610 | 68 | ·9834 | 57 | 1·006 | 46·5 | 1·029 |
| 89·5 | ·9402 | 78·5 | ·9621 | 67·5 | ·9844 | 56·5 | 1·007 | 46 | 1·030 |
| 89 | ·9412 | 78 | ·9631 | 67 | ·9855 | 56 | 1·008 | 45·5 | 1·031 |
| 88·5 | ·9421 | 77·5 | ·9641 | 66·5 | ·9865 | 55·5 | 1·009 | 45 | 1·032 |
| 88 | ·9431 | 77 | ·9651 | 66 | ·9875 | 55 | 1·010 | 44·5 | 1·033 |
| 87·5 | ·9441 | 76·5 | ·9661 | 65·5 | ·9886 | 54·5 | 1·012 | 44 | 1·034 |
| 87 | ·9451 | 76 | ·9671 | 65 | ·9896 | 54 | 1·013 | 43·5 | 1·035 |
| 86·5 | ·9461 | 75·5 | ·9681 | 64·5 | ·9906 | 53·5 | 1·014 | 43 | 1·036 |
| 86 | ·9471 | 75 | ·9691 | 64 | ·9917 | 53 | 1·015 | 42·5 | 1·037 |
| 85·5 | ·9481 | 74·5 | ·9701 | 63·5 | ·9927 | 52·5 | 1·016 | 42 | 1·038 |
| 85 | ·9491 | 74 | ·9711 | 63 | ·9937 | 52 | 1·017 | 41·5 | 1·039 |
| 84·5 | ·9501 | 73·5 | ·9722 | 62·5 | ·9948 | 51·5 | 1·018 | 41 | 1·041 |
| 84 | ·9510 | 73 | ·9732 | 62 | ·9958 | 51 | 1·019 | 40·5 | 1·042 |
| 83·5 | ·9520 | 72·5 | ·9742 | 61·5 | ·9969 | 50·5 | 1·020 | 40 | 1·043 |
| 83 | ·9530 | 72 | ·9752 | 61 | ·9979 | 50 | 1·021 | 39·5 | 1·044 |
| 82·5 | ·9540 | 71·5 | ·9762 | 60·5 | ·9990 | 49·5 | 1·022 | 39 | 1·045 |
| 82 | ·9550 | 71 | ·9772 | **60** | 1·000 | 49 | 1·023 | 38·5 | 1·046 |
| 81·5 | ·9560 | 70·5 | ·9783 | 59·5 | 1·001 | 48·5 | 1·024 | 38 | 1·047 |
| 81 | ·9570 | 70 | ·9793 | 59 | 1·002 | 48 | 1·025 | 37·5 | 1·048 |
| 80·5 | ·9580 | 69·5 | ·9803 | 58·5 | 1·003 | 47·5 | 1·026 | 37 | 1·049 |
| 80 | ·9590 | 69 | ·9814 | 58 | 1·004 | 47 | 1·027 | 36·5 | 1·050 |
| 79·5 | ·9600 | 68·5 | ·9824 | 57·5 | 1·005 | | | | |

*Example.*—The resistance of a copper wire at 48° F. is 200 ohms; what is its resistance at 60° F.?

Resistance at 60° F. = 200 × 1·025 = 205·0 ohms.

For Submarine Cable tests the results are reduced to 75° F. by the following table:—

TABLE 337.—MULTIPLYING COEFFICIENTS (k) FOR REDUCING THE OBSERVED RESISTANCE OF ORDINARY COPPER WIRE AT ANY TEMPERATURE TO 75° F.

| Temp. ° F. | Coeff. | Temp. ° F. | Coeff. | Temp. ° F. | Coeff. | Temp. ° F. | Coeff. | Temp. ° F. | Coeff. |
|---|---|---|---|---|---|---|---|---|---|
| 90 | ·9691 | 79 | ·9917 | 68 | 1·015 | 57 | 1·038 | 46·5 | 1·061 |
| 89·5 | ·9701 | 78·5 | ·9927 | 67·5 | 1·016 | 56·5 | 1·039 | 46 | 1·062 |
| 89 | ·9711 | 78 | ·9937 | 67 | 1·017 | 56 | 1·041 | 45·5 | 1·064 |
| 88·5 | ·9722 | 77·5 | ·9948 | 66·5 | 1·018 | 55·5 | 1·042 | 45 | 1·065 |
| 88 | ·9732 | 77 | ·9958 | 66 | 1·019 | 55 | 1·043 | 44·5 | 1·066 |
| 87·5 | ·9742 | 76·5 | ·9969 | 65·5 | 1·020 | 54·5 | 1·044 | 44 | 1·067 |
| 87 | ·9752 | 76 | ·9979 | 65 | 1·021 | 54 | 1·045 | 43·5 | 1·068 |
| 86·5 | ·9762 | 75·5 | ·9990 | 64·5 | 1·022 | 53·5 | 1·046 | 43 | 1·069 |
| 86 | ·9772 | **75** | 1·000 | 64 | 1·023 | 53 | 1·047 | 42·5 | 1·070 |
| 85·5 | ·9783 | 74·5 | 1·001 | 63·5 | 1·024 | 52·5 | 1·048 | 42 | 1·071 |
| 85 | ·9793 | 74 | 1·002 | 63 | 1·025 | 52 | 1·049 | 41·5 | 1·072 |
| 84·5 | ·9803 | 73·5 | 1·003 | 62·5 | 1·026 | 51·5 | 1·050 | 41 | 1·074 |
| 84 | ·9814 | 73 | 1·004 | 62 | 1·027 | 51 | 1·051 | 40·5 | 1·075 |
| 83·5 | ·9824 | 72·5 | 1·005 | 61·5 | 1·029 | 50·5 | 1·053 | 40 | 1·076 |
| 83 | ·9834 | 72 | 1·006 | 61 | 1·030 | 50 | 1·054 | 39·5 | 1·077 |
| 82·5 | ·9844 | 71·5 | 1·007 | 60·5 | 1·031 | 49·5 | 1·055 | 39 | 1·078 |
| 82 | ·9855 | 71 | 1·008 | 60 | 1·032 | 49 | 1·056 | 38·5 | 1 079 |
| 81·5 | ·9865 | 70·5 | 1·009 | 59·5 | 1·033 | 48·5 | 1·057 | 38 | 1·080 |
| 81 | ·9875 | 70 | 1·010 | 59 | 1·034 | 48 | 1·058 | 37·5 | 1·082 |
| 80·5 | ·9886 | 69·5 | 1·012 | 58·5 | 1·035 | 47·5 | 1·059 | 37 | 1·083 |
| 80 | ·9896 | 69 | 1·013 | 58 | 1·036 | 47 | 1·060 | 36·5 | 1·084 |
| 79·5 | ·9906 | 68·5 | 1·014 | 57·5 | 1·037 | | | | |

*Example.*—The resistance of a copper wire at 57° F. is 300 ohms; what is its resistance at 75° F.?

Resistance at 75° F. $= 300 \times 1·038 = 311·4$ ohms.

By means of the foregoing Table the temperature of the Sea in which a Submarine Cable is laid can be determined provided the resistance of the conductor of the Cable at 75° was ascertained during the course of manufacture. The measured resistance of the Cable when the latter is laid, divided into the resistance at 75° gives a coefficient which in the above Table corresponds to the temperature of the conductor, that is of the Sea.

The reduction to 75° of the Insulation (dielectric) tests is effected by the following Table :—

TABLE 338.—DIVIDING COEFFICIENTS FOR CORRECTING THE OBSERVED RESISTANCE OF GUTTA-PERCHA AT ANY TEMPERATURE TO 75° F

| Temp. ° F. | Coeff. | Temp. ° F. | Coeff. | Temp. ° F. | Coeff. | Temp. ° F. | Coeff. | Temp. ° F. | Coeff. |
|---|---|---|---|---|---|---|---|---|---|
| 90 | ·3197 | 80 | ·6837 | 70 | 1·463 | 60 | 3·128 | 50 | 6·692 |
| 89·5 | ·3320 | 79·5 | ·7102 | 69·5 | 1·519 | 59·5 | 3·250 | 49·5 | 6·951 |
| 89 | ·3449 | 79 | ·7378 | 69 | 1·578 | 59 | 3·376 | 49 | 7·220 |
| 88·5 | ·3583 | 78·5 | ·7663 | 68·5 | 1·639 | 58·5 | 3·506 | 48·5 | 7·500 |
| 88 | ·3722 | 78 | ·7960 | 68 | 1·703 | 58 | 3·642 | 48 | 7·791 |
| 87·5 | ·3866 | 77·5 | ·8269 | 67·5 | 1·769 | 57·5 | 3·783 | 47·5 | 8·093 |
| 87 | ·4016 | 77 | ·8589 | 67 | 1·837 | 57 | 3·930 | 47 | 8·406 |
| 86·5 | ·4171 | 76·5 | ·8922 | 66·5 | 1·908 | 56·5 | 4·082 | 46·5 | 8·732 |
| 86 | ·4343 | 76 | ·9267 | 66 | 1·982 | 56 | 4·240 | 46 | 9·070 |
| 85·5 | ·4501 | 75·5 | ·9627 | 65·5 | 2·059 | 55·5 | 4·405 | 45·5 | 9·422 |
| 85 | ·4675 | **75** | 1·000 | 65 | 2·139 | 55 | 4·575 | 45 | 9·787 |
| 84·5 | ·4856 | 74·5 | 1·039 | 64·5 | 2·222 | 54·5 | 4·753 | 44·5 | 10·17 |
| 84 | ·5044 | 74 | 1·079 | 64 | 2·308 | 54 | 4·937 | 44 | 10·56 |
| 83·5 | ·5240 | 73·5 | 1·121 | 63·5 | 2·397 | 53·5 | 5·128 | 43·5 | 10·97 |
| 83 | ·5443 | 73 | 1·164 | 63 | 2·490 | 53 | 5·327 | 43 | 11·39 |
| 82·5 | ·5654 | 72·5 | 1·209 | 62·5 | 2·587 | 52·5 | 5·533 | 42·5 | 11·84 |
| 82 | ·5873 | 72 | 1·256 | 62 | 2·687 | 52 | 5·748 | 42 | 12·29 |
| 81·5 | ·6100 | 71·5 | 1·305 | 61·5 | 2·792 | 51·5 | 5·970 | 41·5 | 12·77 |
| 81 | ·6337 | 71 | 1·355 | 61 | 2·899 | 51 | 6·202 | 41 | 13·27 |
| 80·5 | ·6582 | 70·5 | 1·408 | 60·5 | 3·012 | 50·5 | 6·442 | 40·5 | 13·78 |

*Example.*—The insulation resistance at 62° F. of a wire insulated with gutta-percha is 500 megohms ; what is the resistance at 75° F. ?

Resistance $= 500 \div 2·687 = 186·1$ megohms.

## Fault Testing.

### *Blavier's Method.*

Insulate further end of line and measure resistance $l$.

Put further end of line to earth, and measure resistance $l_1$.

Resistance of line when good $= L$.

Resistance up to fault $= l_1 - \sqrt{(l - l_1)(L - l_1)}$.

*Overlap Method.*

Measure resistance $l$ from station A, station B insulating.
Measure resistance $l_2$ from station B, station A insulating.
Resistance of line when good = L.

Resistance up to fault from station $A = \frac{L + l - l_2}{2}$.

*Murray's Loop Method.*

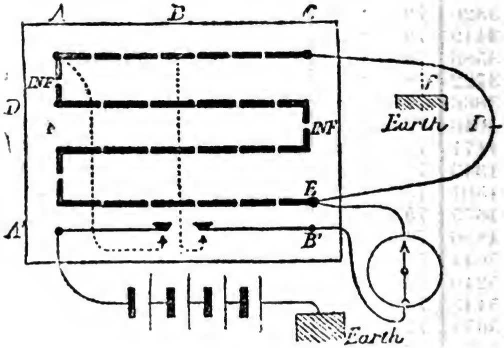



FIG. 84.

C P faulty line. E P good line.

All plugs to be inserted between B and C, also plug between A and D.

10, 100, or 1000 plugs (according to length of loop) to be taken out between A and C.

*Left*-hand key to be held permanently down, and *right*-hand key to be manipulated.

D E to be adjusted till equilibrium is produced.

Resistance from C up to fault $= L\,\frac{b}{b+d}$.

L = total resistance of entire loop (measured by bridge, page 609).

$b$ = resistance unplugged in A B.

$d$ = ,, ,, ,, D E.

*Varley's Loop Method.*

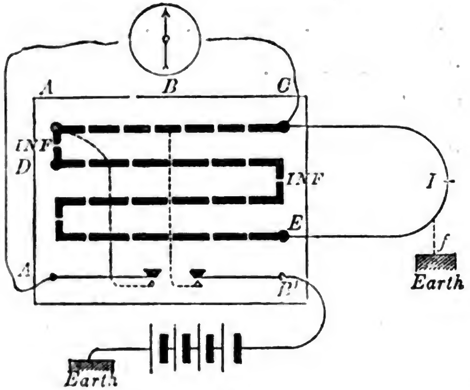



FIG. 85

E P. faulty line. C P good line.

10, 100, or 1000 plugs (according to length of loop) to be taken out between A and B and between B and C.

*Right*-hand key to be held permanently down, and *left*-hand key to be manipulated.

D E to be adjusted till equilibrium is produced.

Resistance from E up to fault $= \frac{bL - ad}{b + a}$.

L = total resistance of entire loop (measured by bridge, page 609).

$a =$ resistance unplugged in B C.

$b =$ ,, ,, ,, A B.

$d =$ ,, ,, ,, D E.

**Inductive or Electrostatic Capacity.**

Inductive capacities are measured by comparing the discharge from a standard condenser with the discharge from the

insulated wire whose capacity is required; the capacities will be in direct proportion to the discharges if the latter are measured on a Thomson reflecting galvanometer.

Inductive capacity of a wire insulated with gutta-percha

$$= \frac{\cdot 170}{\log. \frac{D}{d}} \text{ m. farads per knot, approximately}$$

$$= \frac{\cdot 147}{\log. \frac{D}{d}} \quad ,, \quad ,, \text{ statute mile} \quad ,,$$

where D = diameter of insulating material,

$d$ = ,, conductor.

For india-rubber the values are about 10 to 15 per cent. less.

Inductive capacity of an aerial line

$$= \frac{\cdot 061637}{\log. \frac{4h}{d}} \text{ m. farads per statute mile, approx.}$$

where $d$ = diameter of wire in mils (1 mil. = $\frac{1}{1000}$ in.)

$h$ = height of wire above ground, also in mils.

If there are a large number of wires on the poles the inductive capacity of each wire will be increased to a small extent.

## ELECTRO-CHEMISTRY.

One ampère of current decomposes ·00009324 gramme of water per second, liberating ·000010384 gramme of hydrogen, and ·00008286 gramme of oxygen.

C ampères of current in T seconds will throw down or deposit from a solution of any salt of a metal

CT$a$ grammes, or CT$b$ grains.

where $a$ and $b$ are the values given in the following Table :—

TABLE 339.—VALUES OF $a$ AND $b$, ELECTRO-CHEMICAL DEPOSITS.

| Metal. | $a$ (grammes). | $b$ (grains). |
|---|---|---|
| Hydrogen | ·000010384 | ·00016025 |
| Aluminium | ·00009449 | ·0014582 |
| Magnesium | ·00012430 | ·0019182 |
| Iron (Ferric) | ·00019356 | ·0029869 |
| „ (*Ferrous*) | *·00029035* | *·0044808* |
| Sodium | ·00023873 | ·0036842 |
| Nickel | ·00030425 | ·0046953 |
| Tin (Stannic) | ·00030581 | ·0047085 |
| „ (*Stannous*) | *·00061162* | *·0094387* |
| Copper (Cupric) | ·00032709 | ·0050478 |
| „ (*Cuprous*) | *·00065419* | *·0100960* |
| Zinc | ·00033696 | ·0052001 |
| Potassium | ·00040539 | ·0062561 |
| Gold | ·00067911 | ·0104800 |
| Mercury (Mercuric) | ·00103740 | .0160100 |
| „ (*Mercurous*) | *·00207470* | *·0320170* |
| Lead | ·00107160 | ·0165370 |
| Silver | ·00111800 | ·0172540 |

## Primary Batteries.

A current of 1 ampère for 1 hour in a primary battery will dissolve 1·213 grammes = 18·72 grains of zinc *in each cell*, provided there is no local action.

Quantity of zinc consumed in a primary battery per horse-power-hour

$$= \frac{1{\cdot}995}{E} \text{lbs.},$$

where E is the electromotive force of the battery.

Quantity of any metal (used as the positive plate) consumed in a primary battery per horse-power-hour

$$= \frac{5921{\cdot}8 \times a}{E} \text{ lbs.},$$

where $a$ is the value given in the foregoing table.

Weight for weight primary batteries contain a much greater storage of energy than *Accumulators*, but the energy being produced by the combustion of zinc and the decomposition acids is more expensive to obtain.

### Accumulators.

The largest size accumulators (Electric Power Storage Company) have a capacity of 660 ampère-hours, and weigh, when charged with acid, 265 lbs. The acid (acidulated water), weighs 73 lbs.; the approximate outside dimensions of the glass cells are,—length, 18¼ inches; width, 11¼ inches; height, 13⅜ inches; height over all, 15⅞ inches; each cell contains 31 plates. The cells are charged with a current of from 50 to 60 ampères, and discharged with a current not exceeding 60 ampères. The smaller cells are rather heavier in proportion.

Taking the plates alone, each 1 lb. weight of plates will store about 30,000 foot-pounds of energy.

The acidulated water contains 25 per cent. of sulphuric acid.

The cells should never be left standing uncharged, and should not be discharged to more than ⅔rds of their capacity; they should not be discharged beyond the maximum rate for which they are designed, *i.e.*, a cell which is intended to discharge at a maximum rate of 60 ampères should not be worked at 70 ampères as this would tend to spoil the cells.

About 80 per cent. of the charge can be obtained by discharge if the cells are in good condition.

The electromotive force of accumulators averages 2 volts, though the force is slightly higher when the cells are freshly charged.

The charging electromotive force should not exceed the electromotive force of the accumulator by more than 5 per cent.

If $E$ = the full electromotive force of the charging dynamo and $C$ = the current passing, the *total* rate at which work is being expended on the charging is

$$EC \text{ Watts;}$$

a portion of the work is wasted in heating the accumulator.

The actual rate at which work is being accumulated in the accumulator is

$$E' C$$

where $E'$ is the electromotive force at the accumulator terminals *when the latter are disconnected.*

In the use of accumulators there is first a loss in charging, the loss being due to waste in the dynamo and waste in the accumulator; there is also waste in the accumulator in discharging partly due to heating and partly to local action.

It is more economical to charge accumulators with a weak

current continued for a lengthened period than with a strong current for a short period.

The resistance of an accumulator (when discharging) is

$$\frac{E_1 - E_2}{C}$$

where $E_1$ is the electromotive force on open circuit, and $E_2$ the electromotive force on closed circuit.

The accumulator cells should be kept in as dry (but not warm) a situation as possible.

For charging accumulators a *shunt* wound dynamo must be used.

### Current Induction.

If $e$ = electromotive force set up in a rectilinear conductor of length $l$ moving through a magnetic field of intensity H,
$v$ = velocity of moving conductor,
$\alpha$ = angle the conductor makes with the lines of force,
$\phi$ = angle between the direction of motion and the direction of the force exerted between the magnetic field and the conductor; then,

$$e = \mathrm{H}\, l\, v \sin \alpha \cos \phi.$$

If the conductor is at right angles to and moves so as to cut the lines of force at right angles (in which case sin $\alpha$ cos $\phi$ each equal 1), then 1 Gauss is the strength of field in which a length of one million centimetres of wire moving with unit velocity (1 centimetre per sec.), develops 1 volt of electromotive force = 100 times the strength of 1 C. G. S. field.

The strongest field of a dynamo magnet is about 100 Gausses = 100 × 100 = 10,000 C. G. S. units.

1 C. G. S. magnetic field has 1 line of force per square centimetre.

1 Kapp line = 6,000 C. G. S. lines.

1 ,, ,, per square inch = 930 C. G. S. lines per square centimetre.

A magnetic field whose strength is 100 Gausses contains $\frac{10,000}{930} = 10{\cdot}75$ Kapp lines per square inch.

The Kapp line was proposed as a suitable factory unit because the revolutions of dynamo armatures are usually reckoned per minute instead of per second (60 secs. = 1 minute), and also by dividing by 100, the units expressing the number of magnetic lines are brought to numerical values easily dealt with and remembered.

## DYNAMOS.

### The Series Dynamo.

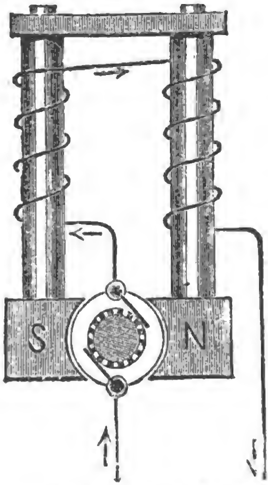



FIG. 86.—Series Wound.

If R = external resistance.

$r_a$ = resistance of armature.

$r_m$ = resistance of field-magnet coils.

E = electromotive force of machine.

$e$ = potential difference between terminals of machine.

$c$ = current strength.

$$e = c\,R = E - (r_a + r_m)\,c$$

$$\left.\begin{array}{l}\text{Ratio of useful electric energy available}\\ \text{in external circuit to total electric}\\ \text{energy developed}\end{array}\right\} = \frac{R}{R + r_a + r_m}$$

$r_m$ may with advantage be made about two-thirds of $r_a$.

Series machines are used for running arc lamps direct.

**The Shunt Dynamo.**

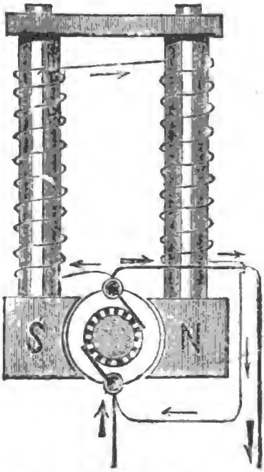



FIG. 87.—Shunt Wound.

If R $=$ external resistance,
$r_a =$ resistance of armature,
$r_s =$ „ „ field-magnet coils,
E $=$ electromotive force of machine,
$e =$ potential difference between terminals of machine,
$c =$ current in external circuit,
$c_a =$ „ „ armature,
$c_s =$ „ „ field-magnet coils,

$$e = c\,R = c_s\,r_s = E - r_a\,(c + c_s)$$

$$E = \left(r_a + \frac{R\,r_s}{R + r_s}\right)c_a = e\,r_a\left(\frac{1}{R} + \frac{1}{r_a} + \frac{1}{r_s}\right)$$

Ratio of useful electric energy available in external circuit to total energy developed $\left.\vphantom{\frac{1}{1}}\right\} = \dfrac{C^2 R}{C^2 R + c_s^2 r_s + c_a^2 r_a}$

In order that a shunt dynamo may give in the external circuit as much as 90 per cent. of its total electric energy the resistance of the shunt must be at least 364 times as great as that of the armature.

Practically the armature resistance may be made $\frac{1}{20}$th of the external resistance, and the shunt resistance 20 times as great.

Shunt machines are used for charging accumulators and for electroplating.

### Separately Excited Dynamos.

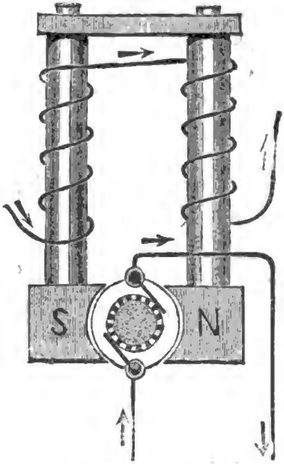



FIG. 88.—Separate Excitation.

If R = external resistance,
$r_m$ = resistance of field-magnet coils,
E = electromotive force of machine,
$c$ = current in external circuit,
$c_m$ = " " field-magnets,

$$E = c\,R$$

$$\left.\begin{array}{l}\text{Ratio of useful electric energy available}\\ \text{in external circuit to total energy}\\ \text{developed}\end{array}\right\} = \frac{C^2 R}{c^2 R + c_m^{\,2} r_m}$$

This gives the distribution of the energy as far as the machine itself is concerned, but there is also a loss of energy in the dynamo used for exciting the field magnets which must be taken into account. This exciting dynamo may be used to excite the field magnets of several dynamos.

## Compound Wound Dynamos.

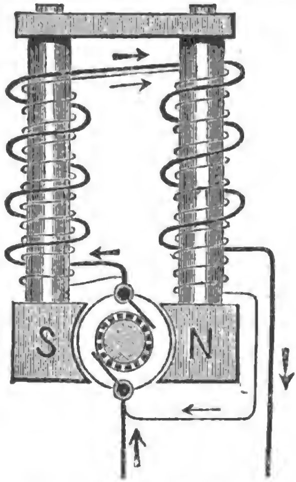



FIG. 89.—Compound Wound.

If $R$ = external resistance.
$r_a$ = resistance of armature.
$r_s$ = ,, ,, field-magnet shunt coils.
$r_m$ = ,, ,, ,, series ,,
$c$ = current in external circuit.
$c_a$ = ,, ,, armature coils.
$c_s$ = ,, ,, shunt ,,
$c_m$ = ,, ,, series ,,

Ratio of useful electric energy available in external circuit to total energy developed $\Bigg\} = \dfrac{c^2 R}{c^2 R + c_a^2 r_a + c_s^2 r_s + c_m^2 r_m}$

$r_s$ should be from 1,000 to 1,500 times $r_a$, and $r_m$ about two-thirds $r_a$.

Compound machines enable a constant potential to be kept at their terminals irrespective of the work to be done in the external circuit. This is required in the case of an installat of incandescent lamps.

## Alternating Current Dynamos.

If E = electromotive force after time $t$.
C = current " " "
T = half period of a complete alternation.
$t$ = time from the instant at which the electromotive was zero when changing from the direction reckoned as negative to that reckoned as positive.
K = a constant.

$$C = \frac{K}{T} \sin \frac{\pi}{T} t$$

If $C_m$ = mean current during the time T.

$$C_m = \frac{2\ K}{\pi\ T}$$

When an alternating current passes through a wire, L, the resistance due to the self-induction in the wire whose ohmic resistance is R and self-induction L is

$$\frac{1}{T}\sqrt{R^2 T^2 + \pi^2 L^2}$$

If C′ be the current indicated on an electro-dynamometer

$$C_m = \frac{9}{10} C'$$

$$\left.\begin{array}{l}\text{Watts consumed in lamps}\\ \text{worked with alternating}\\ \text{currents}\end{array}\right\} = \frac{r\ T\ \sqrt{A^2\ V^2}}{\sqrt{l^2 \pi^2 + r^2 T^2}}$$

Where A = mean current measured on an electro-dynamometer.
V = " potential at terminal of lamps.
$r$ = ohmic resistance of lamp when hot.
$l$ = coefficient of self-induction.
T = half period of a complete alternation.

## Efficiency of Dynamos.

$$\text{Commercial efficiency} = \frac{\text{Electrical energy in external current.}}{\text{Mechanical energy applied at dynamo.}}$$

$$\text{Efficiency of conversion} = \frac{\text{Total electrical energy.}}{\text{Mechanical energy applied at dynamo.}}$$

$$\text{Electrical efficiency} = \frac{\text{Electrical energy in external circuit.}}{\text{Total electrical energy.}}$$

The insulation of the various parts of a dynamo is a point of importance; in particular, measurements should be made of the insulation resistance between the terminals of the machine and its metal bed-plate, and between the segments of the collector and the axle.

In order to determine the efficiency of a dynamo, measurements should be made of the horse-power expended at the pulley (which may be done by means of a Prony brake) and of the energy of the electric currents given out. A good dynamo should have a commercial efficiency of at least 50 per cent.

### Transformers or Converters.

Transformers are used for reducing the high potential from a dynamo to a low potential for working the lamps, the electric power being transmitted more economically at a high than a low potential, as conductors of small diameter can be used, whilst the danger of a high potential in the consumers houses is avoided.

The efficiency of a good transformer at full output is about 96 per cent. and at one-third output 90 per cent. The weight of a transformer varies from 15 to 50 lb. per horse-power according to the size and type.

The rate of alternation of the current in a transformer varies from about 50 to 130 complete alternations per second. Each type of transformer has its best rate of alternations to give the highest efficiency; if this rate is exceeded or reduced an abnormal rise of temperature takes place.

Transformers are usually made to transform from a potential of 2,000 volts or 1,000 volts down to 100 or to 50 volts.

Great care must be taken in the construction of transformers to avoid any leakage from the primary to the secondary circuit.

The following gives dimensions, &c., of a Westinghouse transformer:—

Primary current, 1·5 ampères at 1,000 volts.

Secondary ,, 37·5 ,, ,, 40 ,,

Outside dimensions, 20 × 6 × 4 inches.

Weight of primary wire, 5 lb. gauge, 35 mils.

,, ,, secondary ,, 5½ ,, ,, 120 ,,

The secondary wire is divided into 25 sections joined in parallel.

Weight of iron, 50 lbs.

Efficiency, 97·2 per cent. (?).

## ELECTRIC LAMPS.

### Arc Lamps.

If L = lighting power.
C = current.

$$L \propto 100 \left\{ C + \left(\frac{C}{4}\right)^2 \right\} - 200.$$

Arc lamps for a given expenditure of energy give about 7 times the power of an incandescent lamp.

If $l$ = length of arc in millimetres.
E = electromotive force between the carbons.
C = current flowing.
R = resistance of arc.

$$R = \frac{39}{C} + 1{\cdot}8\,\frac{L}{C}$$

In an arc lamp the top or positive carbon burns about $1\frac{1}{2}$ inches per hour, and twice as fast as the bottom or negative carbon.

A 1000 c.p. lamp requires carbons about $\frac{8}{16}$ths inch in diameter; it is usually run at a potential of 50 volts, and takes about 10 ampères; the power required is about 1 horse. Arc lamps are usually run in series.

### Incandescence Lamps.

A 16 c.p. incandescent lamp is usually run at a potential of 100 volts, and takes ·5 ampère, *i.e.*, requires a power of a little over 3 watts per candle.

1 indicated horse-power will run 8 incandescent lamps of 16 c.p.

Incandescence lamps are usually run in multiple arc.

### Rules and Regulations of the Institution of Electrical Engineers for the Prevention of Fire Risks arising from Electric Lighting (1888).

*Conductors.*

1. They must have a sectional area and conductivity so proportioned to the work they have to do that, if double the current proposed is sent through them, the temperature of such conductors shall not exceed 150° F.

2. The conductors, or their casings, should be placed in sight if possible; and they should always be as accessible as circumstances will permit.

3. Within buildings they should all be insulated; and this rule applies equally to all conductors and parts of fittings which may have to be handled.

4. Whatever insulating material is employed, it should not soften until a temperature of 170° F. has been reached, and in all cases the material must be damp-proof.

5. When leads pass through roofs, floors, walls, or partitions, and where they cross or are liable to touch metallic substances, such as bell wires, iron girders, or pipes, they should be thoroughly protected by suitable additional covering; and where they are liable to abrasion from any cause, or to the depredations of rats or mice, they should be encased in some suitable hard material.

6. In the case of portable fittings with which flexible leads are used, special precautions must be taken.

7. Conductors should be kept as far apart as circumstances will permit, the spacing between them being governed by their potential difference.

8. When conductors are carried in very inflammable structures, precautions should be taken to isolate them therefrom.

9. Conductors which are protected on the outside by lead, or metallic armour of any kind, require the greatest care in fixing, on account of the large conducting surface which would become connected to the core in the event of metallic contact between them.

10. In cases where conductors pass into a building, from one building to another, or from one room to another, precautions should be taken to prevent the possibility of fire or water passing along the course of the conductors.

11. All joints must be mechanically and electrically perfect, to prevent heat being generated at these points. When soldering fluids are used in making joints, the latter should be carefully washed and dried before insulation is applied.

12. Under all circumstances complete metallic circuits must be employed. Gas and water pipes must never form part of the circuit, as their joints are rarely electrically good and therefore become a source of danger.

13. Overhead conductors, whether passing over or attached to buildings, must be insulated at their points of support. Precautions must be taken to obviate all risk of short-circuiting where they are likely to touch a building or other overhead conductors and wires, either by their own falling or by being fallen upon by other conductors.

14. In the case of overhead wires, every main should have a lightning protector at each point where it enters or branches into a building.

15. Metal fastenings for fixing conductors should be avo

but, when unavoidable, some additional covering should protect the conductor from mechanical injury at such fixing points.

16. The insulation of a system of distribution should be such that the greatest leakage from any conductor to earth (and, in case of parallel working, from one conductor to the other, when all branches are switched on, but the lamps, motors, &c., removed), does not exceed one five-thousandth part of the total current intended for the supply of the said lamps, motors, &c.; the test being made at the usual working electromotive force.

17. It will often be found a great convenience and assistance in the prevention of accidents if the positive lead be coloured differently to the negative, or made otherwise distinguishable.

### *Switches.*

18. Every switch or commutator should be of such construction as to comply with the following condition, namely:—That, when the handle is moved or turned to and from the positions of "on" and "off," it is impossible for it to remain in any intermediate position, or to permit of a permanent arc, or heating.

19. The handles of every switch must be completely insulated from the circuit.

20. The main switches of a building should be placed as near as possible to the point of entrance of the conductors, or to the generators of the current if they are within the building itself. Switches should be provided on both leads.

21. Switch-boards should bear clear instructions for their use by the inexperienced.

### *Electrical Fittings Generally.*

22. Switches, commutators, resistances, bare connections, lamps, &c., must be mounted on incombustible bases. Cut-outs mounted on bases of wood rendered uninflammable are admissible. Vulcanite bases are undesirable in damp situations. The cracking of porcelain and earthenware fittings is a source of danger which can be avoided by precautions in fixing.

### *Cut-outs.*

23. All circuits should be protected with cut-outs; and all leads from the mains, or small conductors from larger ones, must be fitted with cut-outs at their branching points.

24. Where fusible cut-outs are used, the section should be so situated within its frame that the fused metal cannot fall where it may cause a "short-circuit" or an ignition.

25. For all main conductors a cut-out should be provided for both the "flow" and "return," and the two fusible sections must not be in the same compartment.

26. The flexible leads of portable fittings must in all cases be protected by cut-outs at their fixed points of connection.

*Arc Lamps.*

27. Arc lamps must always be guarded by lanterns or netted globes, so as to prevent danger from ascending sparks and from falling glass and incandescent pieces of carbon.

28. All parts of the lamps and lanterns which are liable to be handled (except by the persons employed to trim them) should be insulated.

*The Dynamo.*

29. The armatures and field-magnet coils should be thoroughly insulated. Dynamos should always be fixed in dry places, and they must not be exposed to dust flyings or other industrial waste products carried in suspension in the air. They should not be permitted in the working-rooms of mills, where the liability to such dangers exists, or where any inflammable manufactures are carried on or inflammable materials are stored.

30. Motors should be subject to the same conditions; but when it is necessary to use them in positions such as those above referred to, they must be securely cased in, such cases having a non-combustible lining.

*Batteries.*

31. Both primary and secondary batteries should be placed and used under the same precautions as prescribed for dynamos; and the room in which they are placed should be well ventilated. The batteries themselves must be well insulated.

*Transformers.*

32. When these are used to transform either direct or alternating currents of high electro-motive force—that is, from or to an electro-motive force of, say, 200 volts—they, together with their switches and cut-outs, must be placed in a fire- and moisture-proof structure—preferably outside the building for which they are required. No part of such apparatus should be accessible except to the person in charge of their maintenance.

33. In all cases conductors conveying currents of high electro-motive force inside buildings must be specially

exceptionally insulated, cased in, and the casing made fireproof.

34. The positive and negative terminals connected to such conductors should not be permitted to be nearer each other than 12 inches.

35. Transformers which, under normal conditions of load, heat above 150° F., should not be permitted to remain in use.

36. Transformers should be so constructed that under no circumstances whatever should a contact between the primary and secondary coils lead the high E.M.F. into the building.

*Maintenance.*

37. The value of frequently testing and inspecting the apparatus and circuits cannot be too strongly urged as a precaution against fire. Records should be kept of all tests, so that any gradual deterioration of the system may be detected.

38. Cleanliness of all parts of the apparatus and fittings is essential to a good maintenance.

39. No repairs or alterations must be made when the current is "on."

**Three-Wire System.**

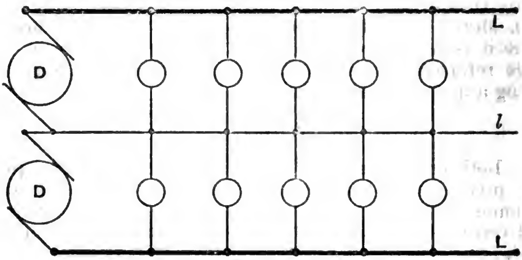



FIG. 90.

In this system of distribution, two equal dynamos, D, D, are joined in series. Three lead-wires are used, two, L, L, being of larger sectional area than the third, *l*, or centre lead. The advantage of the arrangement is that the main leads can be smaller than would be the case if a single dynamo were used and all the lamps were in parallel, whilst by the addition of the third or centre wire the breakage of one or more lamps does not cause the extinction of the other lamps with which they are in series, the continuity of the current being kept up by the centre wire.

## Electric Motors.

Let $E$ = electro-motive force of dynamo.
$e$ = back electro-motive force of motor.
$V$ = potential difference between terminals of dynamo.
$V$ = ,, ,, ,, ,, motor.
$r_1$ = Resistance of dynamo.
$r_2$ = ,, ,, motor.
$R$ = ,, ,, line.
$W_1$ = mechanical work put into dynamo.
$W_2$ = electrical ,, given out by ,,
$w_1$ = mechanical ,, taken out of motor.
$w_2$ = electrical ,, put into ,,
$w_3$ = ,, available in ,,

$$E = V + Cr_1$$

$$E = V + C(r_1 + R)$$

$$e = V - Cr_2$$

$$C = \frac{E - e}{r_1 + R + r_2}$$

$$w_2 = CV \text{ watts}$$

$$w_3 = Ce = C(V - Cr) \text{ watts}$$

$$W_2 = CE \text{ watts}$$

$$\left.\begin{array}{l}\text{Maximum possible electri-}\\\text{cal efficiency of system}\end{array}\right\} = \frac{e}{E}$$

$$\text{Actual electrical efficiency} = \frac{w_1}{C(V + C(r_1 + R))}$$

$$\text{Actual mechanical efficiency} = \frac{w_1}{W}$$

In order to get the greatest possible efficiency the value of $e$ should be as large as possible, *i.e.*, the motor should run at as high a speed as possible, and in order to get as much power as possible with high efficiency E should be as large as possible.

The greatest amount of work is got out of the motor when it runs at such a speed that $e = \frac{E}{2}$. But in this case the efficiency is only 50 per cent., *i.e.*, only half the power given out by the dynamo generator is utilised in the motor. If the motor runs at a higher speed, the work it does becomes less, but its efficiency increases. When the speed becomes such that $e$ nearly equals E, the work done is small, but it is nearly all being utilised.

## Electric Light Cables.

TABLE 340.—ELECTRIC LIGHT CABLES: WEIGHTS, SIZES, AND RESISTANCES. (Silvertown List.)

| Number of Wires in Strand. | Legal Standard Gauge of each Wire. | Diameter. Of each Single Wire. Inch. | Diameter. Of each Single Wire. m/m. | Diameter. Of the Strand. Inch. | Diameter. Of the Strand. m/m. | Equivalent to Solid Wires. Diameter. Inch. | Equivalent to Solid Wires. Diameter. m/m. | Equivalent to Solid Wires. Area. Sq. In. | Equivalent to Solid Wires. Area. Square m/m. | Weight of Conductor. Per Statute Mile. Lbs. | Weight of Conductor. Per Kilometre. Kilogrms. | Resistance at 60° Fahr. Per Statute Mile. Ohms. | Resistance at 60° Fahr. Per Kilometre. Ohms. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 22 | ·028 | ·711 | ... | ... | ·028 | ·711 | ·0006 | 0·397 | 12 | 4 | 72·52 | 45·06 |
| 1 | 21 | ·032 | ·813 | ... | ... | ·032 | ·813 | ·0008 | 0·518 | 16 | 5 | 55·53 | 34·50 |
| 1 | 20 | ·036 | ·914 | ... | ... | ·036 | ·914 | ·0010 | 0·656 | 21 | 6 | 43·87 | 27·25 |
| 1 | 19 | ·040 | 1·02 | ... | ... | ·040 | 1·02 | ·0012 | 0·810 | 26 | 7 | 35·53 | 22·07 |
| 1 | 18 | ·048 | 1·22 | ... | ... | ·048 | 1·22 | ·0018 | 1·167 | 37 | 10 | 24·68 | 15·33 |
| 1 | 17 | ·056 | 1·42 | ... | ... | ·056 | 1·42 | ·0024 | 1·588 | 50 | 14 | 18·13 | 11·26 |
| 1 | 16 | ·064 | 1·62 | ... | ... | ·064 | 1·62 | ·0032 | 2·075 | 65 | 19 | 13·88 | 8·624 |
| 1 | 15 | ·072 | 1·83 | ... | ... | ·072 | 1·83 | ·0040 | 2·626 | 83 | 24 | 10·97 | 6·816 |
| 1 | 14 | ·080 | 2·03 | ... | ... | ·080 | 2·03 | ·0050 | 3·242 | 102 | 29 | 8·884 | 5·520 |
| 1 | 13 | ·092 | 2·34 | ... | ... | ·092 | 2·34 | ·0066 | 4·287 | 135 | 38 | 6·718 | 4·174 |
| 1 | 12 | ·104 | 2·64 | ... | ... | ·104 | 2·64 | ·0085 | 5·480 | 173 | 49 | 5·257 | 3·266 |
| 1 | 11 | ·116 | 2·94 | ... | .. | ·116 | 2·94 | ·0105 | 6·774 | 215 | 61 | 4·225 | 2·625 |
| 1 | 10 | ·128 | 3·25 | ... | ... | ·128 | 3·25 | ·0128 | 8·302 | 262 | 74 | 3·470 | 2·156 |
| 1 | 9 | ·144 | 3·65 | ... | ... | ·144 | 3·65 | ·0162 | 10·50 | 332 | 93 | 2·742 | 1·703 |
| 1 | 8 | ·160 | 4·06 | ... | ... | ·160 | 4·06 | ·0201 | 12·97 | 409 | 115 | 2·221 | 1·380 |
| 3 | 25 | ·020 | ·508 | ·042 | 1·07 | ·034 | ·863 | ·0009 | 0·585 | 19 | 6 | 46·79 | 29·07 |
| 3 | 23 | ·024 | ·609 | ·051 | 1·29 | ·042 | 1·06 | ·0014 | 0·893 | 28 | 8 | 32·50 | 20·19 |
| 3 | 22 | ·028 | ·711 | ·059 | 1·50 | ·049 | 1·24 | ·0019 | 1·216 | 38 | 11 | 23·87 | 14·83 |
| 7 | 25 | ·020 | ·508 | ·060 | 1·54 | ·053 | 1·35 | ·0022 | 1·423 | 45 | 13 | 20·01 | 12·43 |
| 7 | 23 | ·024 | ·609 | ·072 | 1·83 | ·064 | 1·62 | ·0032 | 2·075 | 65 | 19 | 13·89 | 8·630 |
| 7 | 22 | ·028 | ·711 | ·084 | 2·13 | ·075 | 1·90 | ·0044 | 2·849 | 89 | 25 | 10·20 | 6·337 |
| 7 | 21½ | ·030 | ·762 | ·090 | 2·28 | ·080 | 2·03 | ·0050 | 3·242 | 102 | 29 | 8·898 | 5·525 |
| 7 | 20½ | ·033 | ·838 | ·099 | 2·51 | ·088 | 2·23 | ·0061 | 3·923 | 124 | 35 | 7·342 | 4·561 |

TABLE 340 (*continued*).

| Number of Wires in Strand. | Legal Standard Gauge of each Wire. | Diameter. Of each Single Wire. | | Diameter. Of the Strand. | | Equivalent to Solid Wires. Diameter. | | Equivalent to Solid Wires. Area. | | Weight of Conductor. Per Statute Mile. | Weight of Conductor. Per Kilometre. | Resistance at 60 Fahr. Per Statute Mile. | Resistance at 60 Fahr. Per Kilometre. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Inch. | m/m. | Inch. | m/m. | Inch. | m/m. | Sq. In. | Square m/m. | Lbs. | Kilogrms. | Ohms. | Ohms. |
| 7 | 20 | ·036 | ·914 | ·108 | 2·74 | ·096 | 2·43 | ·0072 | 4·65 | 147 | 42 | 6·175 | 3·835 |
| 7 | 19 | ·040 | 1·02 | ·120 | 3·04 | ·107 | 2·71 | ·0089 | 5·77 | 182 | 52 | 5·002 | 3·1079 |
| 7 | 18 | ·048 | 1·22 | ·144 | 3·66 | ·128 | 3·25 | ·0128 | 8·30 | 262 | 74 | 3·473 | 2·158 |
| 7 | 17 | ·056 | 1·42 | ·168 | 4·27 | ·149 | 3·78 | ·0174 | 11·28 | 356 | 100 | 2·552 | 1·585 |
| 7 | 16 | ·064 | 1·63 | ·192 | 4·88 | ·171 | 4·34 | ·0229 | 14·73 | 465 | 132 | 1·953 | 1·213 |
| 7 | 15 | ·072 | 1·83 | ·216 | 5·49 | ·192 | 4·87 | ·0289 | 18·66 | 589 | 166 | 1·543 | ·9589 |
| 7 | 14 | ·080 | 2·03 | ·240 | 6·10 | ·213 | 5·41 | ·0356 | 22·98 | 727 | 205 | 1·253 | ·7785 |
| 19 | 20 | ·036 | ·914 | ·180 | 4·57 | ·159 | 4·03 | ·0198 | 12·74 | 402 | 113 | 2·261 | 1·404 |
| 19 | 19 | ·040 | 1·02 | ·200 | 5·08 | ·176 | 4·47 | ·0243 | 15·72 | 496 | 140 | 1·831 | 1·137 |
| 19 | 18 | ·048 | 1·22 | ·240 | 6·10 | ·211 | 5·35 | ·0349 | 22·66 | 715 | 201 | 1·271 | ·7897 |
| 19 | 17 | ·056 | 1·42 | ·280 | 7·10 | ·247 | 6·27 | ·0479 | 30·91 | 973 | 274 | 1·079 | ·6704 |
| 19 | 16 | ·064 | 1·63 | ·320 | 8·12 | ·282 | 7·16 | ·0624 | 40·25 | 1,270 | 358 | ·7154 | ·4445 |
| 19 | 15 | ·072 | 1·83 | ·360 | 9·14 | ·317 | 8·05 | ·0789 | 50·96 | 1,608 | 453 | ·5652 | ·3512 |
| 19 | 14 | ·080 | 2·03 | ·400 | 10·1 | ·352 | 8·94 | ·0973 | 62·77 | 1,965 | 559 | ·4579 | ·2845 |
| 19 | 13 | ·092 | 2·34 | ·460 | 11·6 | ·404 | 10·7 | ·1282 | 83·20 | 2,625 | 740 | ·3462 | ·2151 |
| 19 | 12 | ·104 | 2·64 | ·520 | 13·2 | ·458 | 11·6 | ·1647 | 106·3 | 3,354 | 945 | ·2709 | ·1683 |
| 37 | 16 | ·064 | 1·63 | ·448 | 11·3 | ·394 | 10·0 | ·1219 | 78·6 | 2,482 | 699 | ·3661 | ·2274 |
| 37 | 15 | ·072 | 1·83 | ·504 | 12·8 | ·443 | 11·2 | ·1541 | 99·58 | 3,142 | 885 | ·2892 | ·1797 |
| 37 | 14 | ·080 | 2·03 | ·560 | 14·2 | ·493 | 12·5 | ·1909 | 122·9 | 3,879 | 1,093 | ·2343 | ·1456 |
| 37 | 13 | ·092 | 2·34 | ·644 | 16·3 | ·566 | 14·3 | ·2516 | 162·6 | 5,130 | 1,445 | ·1772 | ·1101 |
| 37 | 12 | ·104 | 2·64 | ·728 | 18·4 | ·640 | 16·2 | ·3217 | 207·7 | 6,555 | 1,847 | ·1386 | ·0861 |
| 61 | 13 | ·092 | 2·34 | ·828 | 21·0 | ·728 | 18·5 | ·4162 | 268·7 | 8,477 | 2,389 | ·1072 | ·0666 |
| 61 | 12 | ·104 | 2·64 | ·936 | 23·7 | ·823 | 20·9 | ·5219 | 343·4 | 10,832 | 3,052 | ·0839 | ·0521 |

### Insulation of Wires.

For insulating wires india-rubber is preferable to gutta percha, as the latter gets soft when heated. Vulcanized rubber may be raised 200° without becoming deteriorated.

A good electrical and mechanical insulation is given by covering the conductors with pure india-rubber, then vulcanized india-rubber, then india-rubber-coated tape, the whole being vulcanized together, and finally covered with braided tarred flax, and a coating of preservative compound. It is false economy to use any but the very best insulation. For low tension currents (up to 100 volts) the coverings should be such as to give an insulation to the wires of not less than 1,000 megohms per statute mile; for high tension currents (above 100 volts), the insulation should be as high as 5000 megohms per statute mile. It should be distinctly understood that should the cable whose insulation should normally be 5,000 megohms, test as low as 1,000 megohms, it would not do to use this for a low tension circuit, as the lowness of the insulation would not be due to the nature of the insulating material *but to a defect in it*, which defect would be almost certain to become worse in time. The cables should be tested in water at 75°, after immersion for at least 24 hours, a battery of about 400 to 500 volts being used. Tests as to insulation are perfectly useless unless carried out in a thorough manner.

According to the Board of Trade Regulations, the size of the conductor must be such that the maximum current which may have to pass does not exceed 2,000 ampères per square inch, the wire being of pure copper or its equivalent.

### Calculation of Size of Conductor.

To calculate the size of conductor required, let—

$p$ = greatest percentage of fall of E.M.F. along conductor which is to be allowed,

E = E.M.F. at dynamo terminals,

A = maximum number of ampères per square inch wire can safely carry,

$c$ = current wire is required to carry;

then if length of circuit *exceeds* $\frac{p\text{E} \times 400}{\text{A}}$ yds.,

to calculate the sectional area ($a$) which the lead must have, use the formula

$$a = \frac{c}{p\text{E} \times 400} \text{ sq. ins.}$$

If the length of the circuit is *less than*

$$\frac{p\text{E} \times 400}{\text{A}} \text{ yds.,}$$

from the formula $a = \frac{c}{\text{A}}$ sq. ins.

## TELEGRAPH AND TELEPHONE WIRE.

TABLE 341.—RELATIVE DIMENSIONS, LENGTHS, RESISTANCES (AT 60° F.), AND WEIGHTS OF PURE SOFT COPPER WIRE.

(Glover.)

| B.W.G. No. | Diam. Mils. | Area. Sq. In. | Lbs. per Foot. | Lbs. per Mile. | Feet per Lb. | Miles per Lb. | Feet per Ohm. | Ohms per Foot. | Ohms per Mile. | Ohms per Lb. |
|---|---|---|---|---|---|---|---|---|---|---|
| 0000 | 454 | ·1619 | ·6239 | 3294 | 1·603 | ·0003036 | 19966 | ·00005008 | ·2644 | ·00008027 |
| 000 | 425 | ·1419 | ·5468 | 2887 | 1·829 | ·0003464 | 17497 | ·00005715 | ·3018 | ·0001046 |
| 00 | 380 | ·1134 | ·4371 | 2308 | 2·288 | ·0004333 | 13988 | ·00007149 | ·3775 | ·0001636 |
| 0 | 340 | ·09079 | ·3499 | 1848 | 2·858 | ·0005412 | 11198 | ·00008930 | ·4715 | ·0002552 |
| 1 | 300 | ·07069 | ·2724 | 1438 | 3·671 | ·0006952 | 8718 | ·0001147 | ·6056 | ·0004210 |
| 2 | 284 | ·06335 | ·2442 | 1289 | 4·096 | ·0007757 | 7814 | ·0001280 | ·6758 | ·0005242 |
| 3 | 250 | ·05269 | ·2031 | 1072 | 4·925 | ·0009327 | 6498 | ·0001539 | ·8125 | ·0007579 |
| 4 | 238 | ·04449 | ·1715 | 905·3 | 5·832 | ·001105 | 5487 | ·0001822 | ·9623 | ·001063 |
| 5 | 220 | ·03801 | ·1465 | 773·6 | 6·826 | ·001293 | 4689 | ·0002133 | 1·126 | ·001456 |
| 6 | 203 | ·03237 | ·1247 | 658·6 | 8·017 | ·001518 | 3992 | ·0002506 | 1·323 | ·002008 |
| 7 | 180 | ·02545 | ·09808 | 517·8 | 10·20 | ·001931 | 3139 | ·0003186 | 1·682 | ·003249 |
| 8 | 165 | ·02138 | ·08241 | 435·1 | 12·13 | ·002298 | 2637 | ·0003792 | 2·002 | ·004601 |
| 9 | 148 | ·01720 | ·06631 | 350·1 | 15·08 | ·002856 | 2122 | ·0004713 | 2·488 | ·007108 |
| 10 | 134 | ·01410 | ·05435 | 287·0 | 18·40 | ·003485 | 1739 | ·0005749 | 3·036 | ·01058 |
| 11 | 120 | ·01131 | ·04359 | 230·2 | 22·94 | ·004345 | 1394 | ·0007169 | 3·785 | ·01645 |
| 12 | 109 | ·009331 | ·03596 | 189·9 | 27·81 | ·005266 | 1151 | ·0008689 | 4·588 | ·02416 |
| 13 | 95·0 | ·007082 | ·02732 | 144·2 | 36·60 | ·006933 | 874·3 | ·001144 | 6·039 | ·04187 |

TABLE 341.—RELATIVE DIMENSIONS, LENGTHS, RESISTANCES (AT 60° F.), AND WEIGHTS OF PURE SOFT COPPER WIRE—*continued.*

| B.W.G. No. | Diam. Mils. | Area. Sq. In. | Lbs. per Foot. | Lbs. per Mile. | Feet per Lb. | Miles per Lb. | Feet per Ohm. | Ohms per Foot. | Ohms per Mile. | Ohms per Lb. |
|---|---|---|---|---|---|---|---|---|---|---|
| 14 | 83·0 | ·005411 | ·02085 | 110·1 | 47·95 | ·009082 | 667·3 | ·001498 | 7·912 | ·07186 |
| 15 | 72·0 | ·004072 | ·01569 | 82·86 | 63·73 | ·01207 | 502·2 | ·001991 | 10·51 | ·1268 |
| 16 | 65·0 | ·003318 | ·01279 | 67·53 | 78·19 | ·01481 | 409·3 | ·002443 | 12·90 | ·1910 |
| 17 | 58·0 | ·002642 | ·01018 | 53·77 | 98·20 | ·01859 | 325·9 | ·003069 | 16·20 | ·3014 |
| 18 | 49·0 | ·001886 | ·007268 | 38·37 | 137·6 | ·02606 | 232·6 | ·004300 | 22·70 | ·5916 |
| 19 | 42·0 | ·001385 | ·005340 | 28·19 | 187·3 | ·03547 | 170·9 | ·005852 | 30·90 | 1·096 |
| 20 | 35·0 | ·0009621 | ·003708 | 19·58 | 269·7 | ·05108 | 149·4 | ·008427 | 44·49 | 2·273 |
| 21 | 32·0 | ·0008043 | ·003100 | 16·37 | 322·6 | ·06110 | 99·20 | ·01008 | 53·23 | 3·252 |
| 22 | 28·0 | ·0006158 | ·002373 | 12·53 | 421·4 | ·07981 | 75·95 | ·01317 | 69·52 | 5·548 |
| 23 | 25·0 | ·0004909 | ·001892 | 9·989 | 528·6 | ·1001 | 60·54 | ·01652 | 87·21 | 8·730 |
| 24 | 22·0 | ·0003801 | ·001465 | 7·736 | 682·6 | ·1293 | 46·89 | ·02133 | 112·6 | 14·56 |
| 25 | 20·0 | ·0003142 | ·001211 | 6·393 | 825·9 | ·1564 | 38·75 | ·02581 | 136·3 | 21·31 |
| 26 | 18·0 | ·0002545 | ·0009808 | 5·178 | 1020 | ·1931 | 31·39 | ·03186 | 168·3 | 32·49 |
| 27 | 16·0 | ·0002011 | ·0007749 | 4·092 | 1290 | ·2444 | 24·80 | ·04032 | 212·9 | 52·04 |
| 28 | 14·0 | ·0001539 | ·0005933 | 3·133 | 1685 | ·3192 | 18·99 | ·05267 | 278·1 | 88·77 |
| 29 | 13·0 | ·0001327 | ·0005116 | 2·701 | 1955 | ·3702 | 16·37 | ·06108 | 322·5 | 119·4 |
| 30 | 12·0 | ·0001131 | ·0004359 | 2·302 | 2294 | ·4345 | 13·95 | ·07169 | 378·5 | 164·5 |

### TABLE 342.—HARD COPPER TELEGRAPH WIRE.

(Post Office Specification.)

| Weight per Statute Mile. | | | Approximate Equivalent Diameter. | | | Minimum Breaking Weight. | Minimum Number of Twists in 3 Ins. | Maximum Resistance per Mile at 60° F. | Minimum Weight of each Coil of Wire. |
|---|---|---|---|---|---|---|---|---|---|
| Required Standard. | Minimum. | Maximum. | Standard. | Minimum. | Maximum. | | | | |
| Lbs. | Lbs. | Lbs. | Mils. | Mils. | Mils. | Lbs. | | Ohms. | Lbs. |
| 100 | 97½ | 102½ | 79 | 78 | 80 | 330 | 30 | 9·1 | 50 |
| 150 | 146¼ | 153¾ | 97 | 95½ | 98 | 490 | 25 | 6·05 | 50 |
| 200 | 195 | 205 | 112 | 110½ | 113¼ | 650 | 20 | 4·53 | 50 |

The wire must be capable of being wrapped, in six turns, round its own diameter, unwrapped, and again wrapped in six turns round its own diameter in the same direction as the first wrapping, without breaking.

When aërial copper wires are used for telegraphic purposes, resin should be employed as a flux in making joints, and too much heat should not be applied, as it softens the wire and weakens its tensile strength at that point.

Samples taken from coils of the 800-lbs. wire should bear bending round a bar 2½ inches diameter without any signs appearing of the zinc cracking or peeling off; the 600-lbs. wire should similarly bear bending round a bar 2¼ inches in diameter; the 450-lbs. and 400-lbs. wire round a bar 2 inches in diameter; the 200-lbs. wire round a bar 1½ inches in diameter.

## Iron Telegraph Wire

(page 640).

*Test of Galvanizing.*—Take samples from coils and plunge them into a solution of sulphate of copper saturated at 60°; allow them to remain in solution 1 minute, then withdraw and wipe clean. The galvanizing should permit of this process being 4 times performed with each sample without there being any sign of a reddish deposit of metallic copper on the wire, which would be the case if the coating of zinc were too thin.

See also page 643.

TABLE 343.—GALVANIZED IRON TELEGRAPH WIRE.

(Post Office Specification.)

| Diameter. | | | Weight per Mile. | | | Tests for Strength and Ductility. | | | | | | Maximum Resistance per Mile of the Standard Size at 60° Fahr. | Constant, being Standard Weight × Resistance. | Weight of each piece of Coil of Wire. | | Weight of each Bundle. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Required Standard. | Allowed. Minimum. | Allowed. Maximum. | Required Standard. | Allowed. Minimum. | Allowed. Maximum. | Minimum Breaking Weight. | Minimum Number of Twists in 6 Inches. | For Breaking Weight not less than | Minimum Number of Twists in 6 Inches. | For Breaking Weight not less than | Minimum Number of Twists in 6 Inches. | | | Minimum. | Maximum. | Minimum. | Maximum. |
| Mils. | Mils. | Mils. | Lbs. | Lbs. | Lbs. | Lbs. | | Lbs. | | Lbs. | | Ohms. | | Lbs. | Lbs. | Lbs. | Lbs. |
| 242 | 237 | 247 | 800 | 767 | 833 | 2,480 | 15 | 2,550 | 14 | 2,620 | 13 | 6·75 | 5,400 | 90 | 120 | 90 | 120 |
| 209 | 204 | 214 | 600 | 571 | 629 | 1,860 | 17 | 1,910 | 16 | 1,960 | 15 | 9·00 | 5,400 | 90 | 120 | 90 | 120 |
| 181 | 176 | 186 | 450 | 424 | 477 | 1,390 | 19 | 1,425 | 18 | 1,460 | 17 | 12·00 | 5,400 | 90 | 120 | 90 | 120 |
| 171 | 166 | 176 | 400 | 377 | 424 | 1,240 | 21 | 1,270 | 20 | 1,300 | 19 | 13·50 | 5,400 | 90 | 120 | 90 | 120 |
| 121 | 118 | 125 | 200 | 290 | 213 | 620 | 30 | 638 | 28 | 655 | 26 | 27·00 | 5,400 | 40 | 65 | 80 | 130 |

## Sags and Tensions for Suspending Wires.

The tension when the temperature is lowest, *i.e.*, when the strain is greatest, should not exceed $\frac{1}{4}$th of the breaking strain.

The sag varies with the material, but not with the gauge; the tension varies directly with the weight per foot of the wire.

$$d = \frac{l^2 w}{8t}; \quad d = \sqrt{\frac{3l(L-l)}{8}}; \quad L = l + \frac{8d^2}{3l}; \quad t = \frac{l^2 w}{8d}.$$

where
$l$ = span;
$w$ = weight of unit length;
$d$ = sag (or dip);
L = length of wire in span;
$t$ = tension;

also,

$w$ for 400 lbs. iron = ·075758 lb. per foot.
,, 150 ,, copper = ·028409 ,, ,,
,, 100 ,, ,, = ·018939 ,, ,,

and

Coefficient of expansion for iron = ·00000683 per deg. F.
Coefficient of expansion for copper = ·00000956 ,, ,,

TABLE 344.—SAGS AND TENSIONS TO BE OBSERVED IN ERECTING WIRES AT VARIOUS TEMPERATURES.

400-lbs. Iron Wire (No. $7\frac{1}{2}$).

| Span. | 22° F. Low Winter Temperature. | | | 40° F. Ordinary Winter Temperature. | | | 58° F. Average Summer Temperature. | | | 76° F. High Summer Temperature. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sag. | | Tension. | Sag. | | Tension. | Sag. | | Tension. | Sag. | | Tension. |
| Yards. | Ft. | In. | Lbs. | Ft. | In. | Lbs. | Ft. | In. | Lbs. | Ft. | In. | Lbs. |
| 100 | 3 | $1\frac{3}{4}$ | 270 | 3 | 9 | 227 | 4 | $3\frac{1}{4}$ | 200 | 4 | $8\frac{7}{8}$ | 180 |
| 90 | 2 | $6\frac{5}{8}$ | 270 | 3 | $1\frac{3}{4}$ | 219 | 3 | $2\frac{3}{4}$ | 190 | 4 | $0\frac{7}{8}$ | 169 |
| 80 | 2 | $0\frac{1}{4}$ | 270 | 2 | $7\frac{1}{8}$ | 210 | 3 | $0\frac{3}{4}$ | 178 | 3 | $5\frac{5}{8}$ | 157 |
| 70 | 1 | $6\frac{1}{2}$ | 270 | 2 | $1\frac{1}{4}$ | 198 | 2 | $6\frac{1}{2}$ | 164 | 2 | $10\frac{7}{8}$ | 143 |
| 60 | 1 | $1\frac{5}{8}$ | 270 | 1 | 8 | 184 | 2 | $0\frac{3}{4}$ | 148 | 2 | $4\frac{3}{4}$ | 128 |
| 50 | 0 | $9\frac{1}{2}$ | 270 | 1 | $3\frac{1}{2}$ | 165 | 1 | $7\frac{3}{4}$ | 130 | 1 | $11\frac{1}{4}$ | 110 |

TABLE 344.—TABLE OF SAGS, ETC. (*continued*).

150-lbs. Hard-drawn Copper Wire (No. 12½).

| Yards. | Ft. | In. | Lbs. | Ft. | In. | Lbs. | Ft. | In. | Lbs. | Ft. | In. | Lbs. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 100 | 2 | 8 | 120 | 3 | 7 | 89 | 4 | 3⅞ | 74 | 4 | 11½ | 64 |
| 90 | 2 | 2 | 120 | 3 | 1 | 84 | 3 | 9½ | 69 | 4 | 4⅛ | 60 |
| 80 | 1 | 8⅜ | 120 | 2 | 6⅞ | 80 | 3 | 2½ | 64 | 3 | 8⅞ | 54½ |
| 70 | 1 | 3⅝ | 120 | 2 | 1¾ | 73 | 2 | 8⅝ | 57½ | 3 | 2½ | 49 |
| 60 | 0 | 11⅝ | 120 | 1 | 9 | 66 | 2 | 3⅛ | 51 | 2 | 8¼ | 43 |
| 50 | 0 | 8 | 120 | 1 | 4⅝ | 58 | 1 | 10 | 44 | 2 | 2⅜ | 36½ |

100-lbs. Hard-drawn Copper Wire (No. 14).

| Yards. | Ft. | In. | Lbs. | Ft. | In. | Lbs. | Ft. | In. | Lbs. | Ft. | In. | Lbs. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 100 | 2 | 8 | 80 | 3 | 7 | 59 | 4 | 3⅞ | 49 | 4 | 11½ | 43 |
| 90 | 2 | 2 | 80 | 3 | 1 | 56 | 3 | 9½ | 46 | 4 | 4⅛ | 40 |
| 80 | 1 | 8⅜ | 80 | 2 | 6⅞ | 53 | 3 | 2½ | 42½ | 3 | 8⅞ | 36 |
| 70 | 1 | 3⅝ | 80 | 2 | 1¾ | 49 | 2 | 8⅝ | 38 | 3 | 2½ | 33 |
| 60 | 0 | 11⅝ | 80 | 1 | 9 | 44 | 2 | 3⅛ | 34 | 2 | 8¼ | 29 |
| 50 | 0 | 8 | 80 | 1 | 4⅝ | 39 | 1 | 10 | 29 | 2 | 2⅜ | 24 |

## Copper Wire.

### *Conductivity of Copper Wire.*

$$\text{Percentage of conductivity} = \frac{l^2 \times 22{\cdot}61}{w \times k \times r}.$$

$l$ = length of wire in feet.
$w$ = weight of wire in grains.
$r$ = resistance of wire in ohms.
$k$ = temperature coefficient (p. 604).

*Example.*—The resistance of a copper wire 35 feet ($l$) long and weighing 297 grains ($w$), was ·932 ohm ($r$), the temperature being 68° F.; what was the percentage of conductivity of the wire?

From Table, p. 604, $k = 1{\cdot}015$, therefore

$$\text{Percentage of conductivity} = \frac{35 \times 35 \times 22{\cdot}61}{297 \times 1{\cdot}015 \times {\cdot}932} = 98{\cdot}6.$$

### *Resistance of Copper Wire.*

Resistance per mile of pure soft copper wire at 60° F., $d$ mils. in diameter $= \dfrac{54402}{d^2}$ ohms.

Resistance per mile of pure soft copper wire at 60° F. weighing $w$ lbs. $= \dfrac{872{\cdot}2}{w}$ ohms.

Weight of pure soft copper wire 1 mile long having a resistance of 1 ohm at 60° = 872·2 lbs.

Length in yards of pure soft copper wire having a sectional area of $a$ sq. ins. required to give a resistance of $r$ ohms at 60° F. = $ra \times 41{,}161$. If

$l$ = length of a wire.
$a$ = sectional area.
$d$ = diameter.
$w$ = weight.
$r$ = resistance.

$$r = \frac{l}{a}\kappa = \frac{l}{d^2}\kappa' = \frac{l}{w}\kappa''.$$

Where $\kappa$, $\kappa'$, and $\kappa''$ are the resistances of a wire of unit dimensions. For pure soft copper at 60° F., if $l$ is in feet, $a$ in square inches, $d$ in mils. ($\frac{1}{1000}$th in.) and $w$ in grains (7000 grains = 1 lb.).

$$\kappa = \cdot 000008098,\ \kappa' = 10 \cdot 311,\ \kappa'' = \cdot 2190.$$

The resistance of a copper wire increases about ·21 per cent. per 1° F. If

$r$ = resistance at $t$° F.
R = „ „ T° F.
$R = r(1 + \cdot 0021(T - t))$ approximately.
„ $= r(1 \cdot 0020935)^{T-t}$ more exactly.

## Iron Wire.

Two qualities of iron wire are used by the Postal Telegraph Department for aërial line purposes, known as low resistance and high resistance wire. The low resistance wire may consist either of "special blend" iron, giving a mean resistance of 11·3 ohms per mile at 60° F. for the standard gauge of 171 mils. (No. 7½ B. W. G.): or of "charcoal" iron, giving under the same conditions a resistance of 11·2 ohms per mile. The high resistance wire which is more generally used (see Specification, page 630) of the same gauge has a mean resistance of 12·7 ohms per mile, but is cheaper in price. The low resistance iron is used for circuits over about 200 miles in length, its breaking strain is rather less than that of the high resistance wire.

1 foot-grain of pure iron has a resistance of 1·097 ohms at 0°C. (32 F.).

1 ohm-mile (a wire 1 mile long, having a resistance of 1 ohm) of pure iron, weighs 4368·94 lbs.

Ditto, low resistance blend-wire weighs 4520 lbs.
Ditto, „ „ charcoal „ 4480 „
Ditto, high „ „ „ 5080 „

To determine the resistance R at a temperature $t$° F. the ($r$) at a temperature $t$° being known

$$R = r(1 \cdot 0027)^{t-t}.$$

## TELEGRAPHY.

*Connections of Apparatus on the Morse System adopted by the Postal Telegraph Department.*

### SINGLE CURRENT SYSTEM.

DIRECT WRITER (Combination Instrument.)

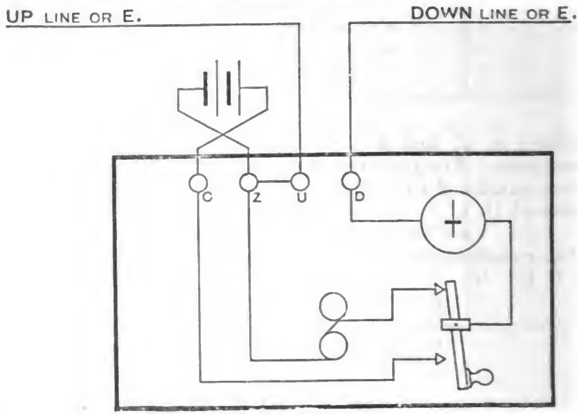



FIG. 91.

DIRECT SOUNDER OR WRITER.

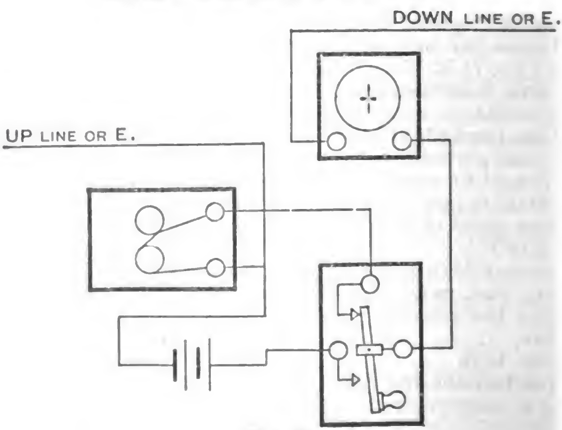



FIG. 92.

SOUNDER WITH RELAY.

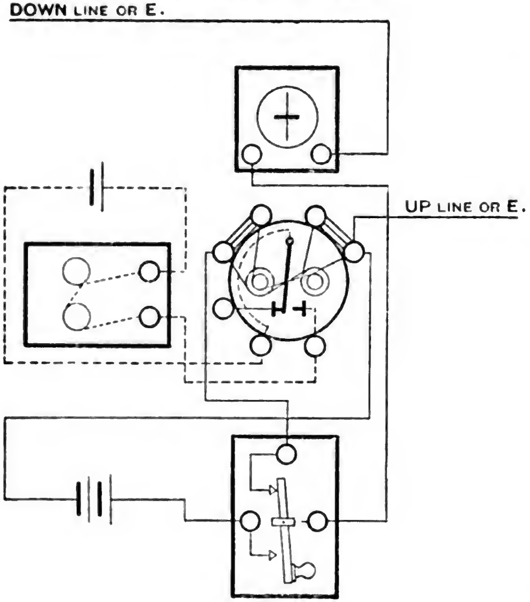



FIG. 93.

DIRECT WRITER. Duplex: with Switch.

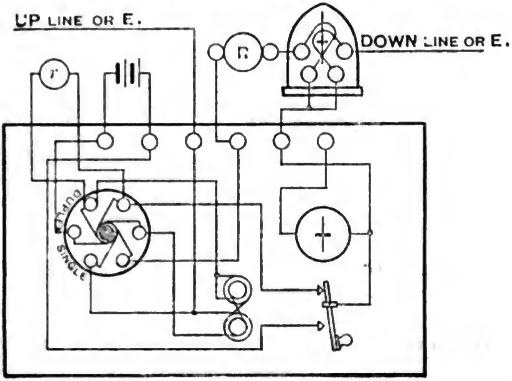



FIG. 94.

All the systems require from 15 to 20 milliampères of current.

The Direct Writer Duplex system is suitable for circuits up to about 25 miles in length. The switch is employed for the purpose of changing the connections to the arrangement for ordinary working, should the insulation of the line become such as to render a proper balance by means of the Rheostat R difficult or impossible, and duplex working consequently impossible also. R is a fixed resistance equal as nearly as possible to the resistance of the battery.

TABLE 345.—TELEGRAPH POLES.

| SIZES OF LIGHT POLES. | | | | SIZES OF STOUT POLES. | | | |
|---|---|---|---|---|---|---|---|
| Length in Feet. | Diameter at Top. Inches. | | Minimum Diameter at 5 Feet from Butt End. Inches. | Length in Feet. | Diameter at Top. Inches. | | Minimum Diameter at 5 Feet from Butt End. Inches. |
| | Minimum. | Maximum. | | | Minimum. | Maximum. | |
| 18 | 5 | $5\frac{3}{4}$ | $6\frac{1}{2}$ | 18 | $5\frac{1}{2}$ | $6\frac{1}{2}$ | $7\frac{1}{4}$ |
| 20 | 5 | $5\frac{3}{4}$ | $6\frac{1}{2}$ | 20 | $5\frac{1}{2}$ | $6\frac{1}{2}$ | $7\frac{1}{2}$ |
| 22 | 5 | $5\frac{3}{4}$ | $6\frac{3}{4}$ | 22 | $5\frac{1}{2}$ | $6\frac{3}{4}$ | $7\frac{3}{4}$ |
| 24 | 5 | $5\frac{3}{4}$ | 7 | 24 | $5\frac{1}{2}$ | $6\frac{3}{4}$ | 8 |
| 26 | 5 | 6 | $7\frac{1}{4}$ | 26 | $5\frac{3}{4}$ | 7 | $8\frac{1}{4}$ |
| 28 | 5 | $6\frac{1}{4}$ | $7\frac{3}{4}$ | 28 | 6 | $7\frac{1}{4}$ | $8\frac{3}{4}$ |
| 30 | 5 | $6\frac{1}{4}$ | 8 | 30 | 6 | $7\frac{1}{4}$ | 9 |
| 32 | $5\frac{1}{4}$ | $6\frac{1}{2}$ | $8\frac{1}{4}$ | 32 | $6\frac{1}{4}$ | $7\frac{1}{2}$ | $9\frac{1}{4}$ |
| 34 | $5\frac{1}{4}$ | $6\frac{3}{4}$ | $8\frac{3}{4}$ | 34 | $6\frac{1}{4}$ | $7\frac{3}{4}$ | $9\frac{3}{4}$ |
| 36 | $5\frac{1}{2}$ | 7 | 9 | 36 | $6\frac{1}{2}$ | $7\frac{3}{4}$ | 10 |
| 38 | $5\frac{1}{2}$ | 7 | $9\frac{1}{4}$ | 38 | $6\frac{1}{2}$ | $7\frac{3}{4}$ | $10\frac{1}{4}$ |
| 40 | $5\frac{1}{2}$ | $7\frac{1}{4}$ | $9\frac{3}{4}$ | 40 | $6\frac{1}{2}$ | 8 | $10\frac{3}{4}$ |
| 45 | $5\frac{3}{4}$ | $7\frac{1}{2}$ | $10\frac{1}{2}$ | 45 | $6\frac{3}{4}$ | $8\frac{1}{2}$ | $11\frac{1}{2}$ |
| 50 | 6 | $7\frac{3}{4}$ | $11\frac{1}{4}$ | 50 | 7 | $8\frac{3}{4}$ | $12\frac{1}{4}$ |
| 55 | 6 | 8 | 12 | 55 | $7\frac{1}{4}$ | 9 | 13 |
| 60 | 6 | 8 | $12\frac{1}{2}$ | 60 | $7\frac{1}{2}$ | 9 | $13\frac{1}{2}$ |

### Telegraphic Solder.

Equal parts by weight of ingot tin and pig lead.

### Materials and Tools for constructing a 300 Mile Iron Pole Telegraph Line of 1 Wire.

*Materials.*

6,000 iron tubular and conical telegraph poles attached to

base pile for driving, the pole complete not weighing more than 100 lbs.; length over all when jointed 18 ft. Length of cast iron base pile about 4 ft., and tube about 14 ft. 6 in., with slit-joint between base pile and tube.

6,000 soft iron rings for caulking into base plate.

6,000 lightning rods, 18 ins. long, to surmount poles.

6,150 insulators, Cordeaux pattern.

4 Hand rammers, for driving base piles.

14 tons No. 14 hand-drawn copper wire, 103 lbs. to the mile, 340 lbs. breaking strain; resistance about 8 ohms per mile.

$\frac{3}{4}$ cwt. best tin solder; 4 gals. soldering solution in gallon jars.

250 anchor plates, stay-rods, stay-wires, clips, &c., complete, for angle poles.

$2\frac{1}{2}$ cwt. No. 18 soft copper wire for binding wire to insulator.

$\frac{1}{2}$ cwt. No. 20 tinned copper wire for jointing line wire.

1 wire dynamometer vice for copper wire.

*Construction Tools.*

3 pairs small-draw vices and keys for No. 14 copper wire.
2 pairs devil's claws.
2 fire-pots.
6 8-in. cutting-pliers.
3 10-in. flat bastard files.
6 soldering-irons, large.
2 tool baskets.
12 lbs. lump sal-ammoniac.
3 large hammers.
2 sledge-hammers.
6 steel wedges.
1 2-ft. rule.
6 Picks. handled.
6 shovels.
6 spades.
3 jumpers.
2 iron punners, handled.
2 crow-bars. steel-pointed.
2 wire-drums and barrows, light and portable.
3 bill-hooks.
3 15-ft. wooden ladders.
3 American axes.
2 hand-saws.
2 saw-files.
2 screw-hammers.

## TELEPHONES.

The limiting distance over which *good* speaking is possible in the case of *cables* and *underground work* is reached when the "KR." is about 8000, KR being the product of the *Total* Inductive Capacity and the *Total* Conductor Resistance of the Line. If the value of KR exceeds 8,000, the speaking commences to become difficult.

Through underground Wire No. 18 Copper and No. 7½ Gutta-percha, the *good*-speaking limit is about 36 miles.

If the working is carried on through a looped wire *with no earth used*, the value KR (*i.e.*, the capacity of the whole length of wire multiplied by the total resistance of the whole length of wire) must be divided by 4, to give the working value of the loop.

In the case of an *overhead iron wire loop* the KR must not exceed 5,000; with a *copper aërial loop* the limit exceeds 30,000, the two wires of the loop in each case being on the same poles.

## LIGHTNING CONDUCTORS.

### CODE OF RULES FOR THE ERECTION OF LIGHTNING CONDUCTORS (*Lightning Rod Conference*).

*Points.*—The point of the terminal should not be sharp, not sharper than a cone of which the height is equal to the radius of its base. But a foot lower down a copper ring should be screwed and soldered on to the upper terminal, in which ring should be fixed three or four sharp copper points, each about 6 in. long. It is desirable that these points be so platinized, gilded, or nickel-plated, as to resist oxidation.

*Upper Terminals.*—The number of conductors or points to be specified will depend upon the size of the building, the material of which it is constructed, and the comparative height of the several parts. No general rule can be given for this; but the architect must be guided by circumstances. He must, however, bear in mind that even ordinary chimney-stacks, when exposed, should be protected by short terminals connected to the nearest rod, inasmuch as accidents often occur owing to the good conducting power of the heated air and soot in a chimney.

*Insulators.*—The rod is not to be kept from the building by glass or other insulators, but attached to it by metal fastenings.

*Fixing.*—Rods should preferentially be taken down the side of the building which is most exposed to rain. They should be held firmly, but the holdfasts should not be driven in so tightly as to pinch the rod, or prevent the contraction and expansion produced by changes of temperature.

*Factory Chimneys.*—These should have a copper band round the top, and stout, sharp, copper points, each about 1 ft. long, at intervals of two or three feet throughout the circumference, and the rod should be connected with all bands and metallic masses in or near the chimney. Oxidation of the joints must be carefully guarded against.

*Ornamental Ironwork.*—All vanes, finials, ridge ironwork &c., shall be connected with the conductor, and it is not absolutely necessary to use any other point than that afforded by such ornamental ironwork, provided the connection be perfect and the mass of ironwork considerable. As, however, there is risk of derangement through repairs, it is safer to have an independent upper terminal.

*Material for Rod.*—Copper, weighing not less than 6 oz. per foot run, and the conducting of which is not less than 90 per cent. of that of pure copper, either in the form of tape or rope of stout wires, no individual wire being less than No. 12 B. W. C. Iron may be used, but should not weigh less than $2\frac{1}{4}$ lbs. per foot run.

*Joints.*—Although electricity of high tension will jump across bad joints, they diminish the efficacy of the conductor, therefore every joint, besides being well cleaned, screwed, scarfed, or riveted, should be thoroughly soldered.

*Protection.*—Copper rods to the height of 10 feet above the ground should be protected from injury and theft, by being enclosed in an iron pipe reaching some distance into the ground.

*Painting.*—Iron rods, whether galvanised or not, should be painted; copper ones may be painted or not according to architectural requirements.

*Curvature.*—The rod should not be bent abruptly round sharp corners. In no case should the length of the rod between two joints be more than half as long again as the line joining them. When a stringcourse or other projecting stonework will admit of it, the rod may be carried straight through, instead of round the projection. In such a case the hole should be large enough to allow the conductor to pass freely, and allow for expansion, &c.

*Extensive Masses of Metal.*—As far as practicable it is desirable that the conductor be connected to extensive masses of metal, such as hot-water pipes, &c., both internal and external; but it should be kept away from all soft metal pipes, and from internal gas-pipes of every kind. Bells inside well-protected spires need not be connected.

*Earth Connection.*—It is essential that the lower extremity of the conductor be buried in permanently damp soil; hence proximity to rain-water pipes, and to drains, is desirable. It is a very good plan to make the conductor bifurcate close below the surface of the ground, and adopt two of the following methods for securing the escape of the lightning to earth. A strip of copper tape may be led from the bottom of the rod to the nearest gas or water *main*—not merely to a lead pipe—and be soldered to it; or a tape may be soldered to a sheet of copper 3 ft. × 3 ft. and $\frac{1}{16}$th in. thick, buried in permanently wet earth, and surrounded by cinders or coke; or many yards of the tape may be laid on a trench filled with coke, taking care that the surfaces of copper are, as in previous cases, not less than 18 square feet. Where iron is used for the rod, a galvanized iron plate of similar dimensions should be employed.

*Inspection.*—Before giving his final certificate, the architect should have the conductor satisfactorily examined and tested by a qualified person, as injury to it often occurs up to the latest period of the works from accidental causes, and often from the carelessness of workmen.

*Collieries.*—Undoubted evidence exists of the explosion of fire-damp in collieries through sparks from atmospheric electricity being led to the mine by the wire ropes of the shaft and the iron rails of the galleries. Hence the head-gear of all shafts should be protected by proper lightning conductors.

# INDEX.

THE END.

BRADBURY, AGNEW, & CO. LD., PRINTERS, WHITEFRIARS.

*Reference is made to page* 565.